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This report presents the findings, conclusions, and recommendations of the Health Effects Study, a multidisciplinary research project which evaluates the health significance of using treated wastewater for indirect potable water reuse by groundwater replenishment. The focus of the study was the Whittier Narrows Groundwater Recharge Project, located in Los Angeles County, California, where disinfected, filtered secondary effluent blended with local storm runoff and imported river water has been used for replenishment since 1962.

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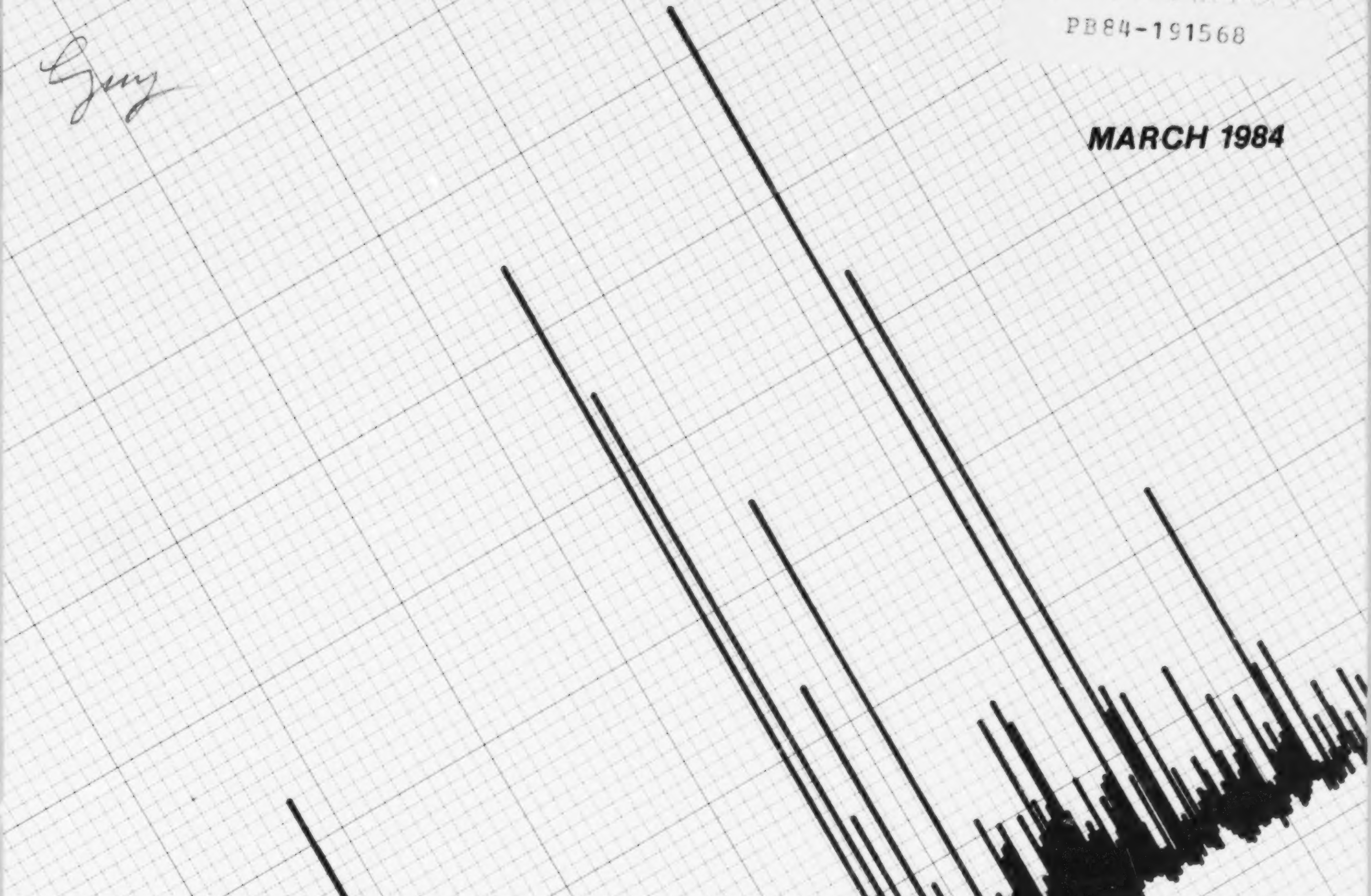

HEALTH EFFECTS STUDY

COUNTY SANITATION DISTRICTS OF LOS ANGELES COUNTY

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FINAL REPORT
MARCH 1984

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- THE ORANGE AND LOS ANGELES COUNTIES WATER REUSE STUDY WHICH WAS FUNDED BY THE FOLLOWING AGENCIES:
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CHAPTER I
SUMMARY

INTRODUCTION

Southern California, like many semi-arid regions of the United States, does not receive sufficient water from local sources to support the considerable population of the area. Almost two-thirds of the water supply is imported 200 to 500 miles from the point of use. The remainder is derived from local groundwater basins. In some areas, the occurrence of overdraft conditions and saltwater intrusion has led to the adjudication of groundwater extractions and/or the implementation of artificial groundwater replenishment. Water sources used for groundwater replenishment include surface runoff, imported river water and, in some cases, treated wastewater (reclaimed water).

There is considerable uncertainty at this time regarding the sufficiency of water supplies for the future water needs of the area. Population growth projections coupled with reductions in imported water deliveries suggest that, by the late 1980s, water needs may exceed available supplies. These water shortage predictions have stimulated regional planning activities aimed at optimizing available water supplies through conservation efforts and developing new local sources of supply through conjunctive groundwater storage and water reclamation. Foremost among these planning efforts is the Orange and Los Angeles Counties Water Reuse Study, which has identified the most viable wastewater reclamation projects within the South Coast Region and has developed a financial and institutional scheme for their implementation. Of all the reclamation projects under consideration, groundwater replenishment represents the largest and potentially most economical use of reclaimed water.

Despite this economic incentive, implementation of proposed groundwater replenishment projects is constrained by concerns over the potential health impacts of the indirect use of reclaimed water for potable purposes. Health issues associated with groundwater replenishment include the acute and chronic effects of trace metals, minerals, pathogens and organic compounds which, if present in reclaimed water, may ultimately become part of a potable water supply. Available information on existing groundwater replenishment projects in Southern California has never shown any evidence of impaired water quality or adverse health effects. Yet, it is recognized that this information is insufficient for rigorous evaluation of the possible long-term health implications associated with indirect potable reuse.

The projects in Los Angeles and Orange Counties provided an opportunity to gather data needed to evaluate the health significance of water reuse by groundwater replenishment. A work plan was developed by the Los Angeles County Sanitation Districts which incorporated multidisciplinary research recommendations proposed by a "blue ribbon" panel of experts convened by the California State Water Resources Control Board, the Department of Water Resources, and the

Department of Health Services. The work plan formed the basis for the Health Effects Study, which formally began in November 1978. The focus of the study was the Whittier Narrows groundwater replenishment project, located in the Montebello Forebay area of Los Angeles County, where disinfected filtered secondary effluent, blended with storm runoff and imported river water, has been used for replenishment since 1962. Other work consisted of conducting preliminary background evaluations for proposed replenishment sites in Los Angeles and Orange Counties.

STUDY GOALS AND OBJECTIVES

The primary goal of the Health Effects Study was to develop a data base which would enable health and regulatory authorities to determine whether the use of reclaimed water for groundwater replenishment at the Whittier Narrows project should be maintained at the present level, cut back, or expanded. Two objectives were necessary to meet this goal; first, to determine if the historical level of reuse had impacted either groundwater quality or human health, and second, to assess the relative impacts of the different replenishment sources on groundwater quality. A second goal of the study was to provide information to the California Department of Health Services to use in establishing statewide reclamation criteria for groundwater replenishment.

A wide range of research tasks was undertaken to meet these objectives, including 1) water quality characterizations of groundwater, reclaimed water, and other replenishment water supplies in terms of their microbiological and inorganic chemical quality, 2) toxicological and chemical studies of groundwater, reclaimed water, and other replenishment water supplies to isolate and identify health-significant organic constituents, 3) percolation studies to evaluate the efficacy of soil in attenuating inorganic and organic chemicals in reclaimed water, 4) hydrogeological studies to determine the movement of reclaimed water throughout the groundwater basin and the relative contribution of reclaimed water to municipal water supplies, and 5) epidemiological studies of populations ingesting reclaimed water to determine if their health characteristics differ significantly from a demographically similar control population.

Expenditures for the study amounted to approximately $1.6 million. A total of $1,134,000 was provided by the Orange and Los Angeles Counties Water Reuse Study, of which 87.5 percent was funded by the Environmental Protection Agency and the California State Water Resources Control Board, and the remainder by six local water and wastewater agencies (the Metropolitan Water District of Southern California, Los Angeles Department of Water and Power, City of Los Angeles, Orange County Water District, County Sanitation Districts of Los Angeles County, County Sanitation Districts of Orange County). An additional $500,000 was provided for the epidemiology work by the EPA Health Effects Research Laboratory and the California Department of Water Resources. The majority of study tasks were performed by the Los Angeles County Sanitation Districts. Subcontracted work consisted of the epidemiology study (University of California at Los Angeles, School of Public Health), and portions of the trace organics analyses (Metropolitan Water District of Southern California), hydrogeologic studies (Bookman-Edmonston Engineering, Inc.), and toxicity testing (University of

Southern California Cancer Research Center). Assistance and direction during the course of the study were provided by two technical advisory committees, and the California Department of Health Services.

Specific study findings, conclusions, and recommendations are summarized below in relation to the stated goals and objectives; a detailed study summary is then presented in the remainder of the chapter.

GOAL

Provide information to health and regulatory authorities to determine whether the use of reclaimed water at the Whittier Narrows groundwater replenishment project should be maintained at its present level, cut back, or expanded.

OBJECTIVES

A. Determine whether the historical level of groundwater replenishment with reclaimed water has had an adverse impact on the quality of the area's groundwater or the health of individuals ingesting the groundwater.

B. Assess the relative impacts of the various replenishment sources on groundwater quality.

FINDINGS

1. Groundwater and reclaimed water complied with all Federally prescribed drinking water regulations for microorganisms, and inorganic and organic chemicals.

2. No viruses were detected in groundwater or chlorinated reclaimed water samples.

3. Analyses for health significant organic compounds not currently regulated by Federally prescribed drinking water standards showed that groundwater and imported water concentrations did not exceed guidelines set by the California Department of Health Services' "action levels" or National Academy of Sciences' "suggested no-adverse-response levels" for chronic ingestion of specific trace organics in drinking water. Concentrations in reclaimed water and storm water were variable and on occasion exceeded levels set by both of these guidelines.

4. Average concentrations of trace organics in groundwater did not exceed the theoretical lifetime risk assessment values calculated in the proposed EPA Water Quality Criteria for priority organics even though average concentrations in reclaimed water, imported water, and storm water did exceed some of the water quality criteria.

5. A 1981 health survey of women residing in the Montebello Forebay study area, which controlled for the potential confounding effects of factors such as smoking, alcohol consumption, bottled water usage, and length of residence, showed no elevated levels of specific illnesses or other measures of general health.

6. Evaluation of health and vital statistics data for the period 1969-80 showed that residents of the area that received reclaimed water experienced no increased rates of infectious diseases, congenital malformations, infant and neonatal mortality, low birth weight, cancer incidence, or deaths due to heart disease, stroke, stomach cancer, rectal cancer, bladder cancer, colon cancer, or all cancers combined, when compared to residents of two control areas that did not receive reclaimed water.

7. Concentrated organic residues derived from all replenishment sources and groundwaters elicited mutagenic responses in bacterial tests related to the presence of a mixture of toxic organic compounds. Chemical and biological assays indicated that low levels of compounds belonging to two classes of organics, the organic halides and epoxides, may have contributed to the mutagenicity. Although there are no drinking water standards or water quality risk assessment data for these two classes of chemicals, members of each group are known to be mutagens and animal carcinogens. Since positive chemical identification of specific mutagens from these two classes could not be made, and since no direct evidence of adverse human health effects was detectable in the epidemiological studies, the biological significance of these materials to humans, at the low levels detected, remains in doubt. Although there was evidence implicating the use of chlorine in industry or in water disinfection as one factor in the occurrence of some of these compounds, other sources may also be important. The presence of such mutagens in groundwater may not be unique to or uniquely aggravated by groundwater replenishment activities. Rather, their presence may reflect the same spectrum of compounds responsible for low-level mutagenesis reported in various drinking water samples nationwide.

CONCLUSIONS

1. Extensive evaluation of the Whittier Narrows groundwater replenishment project did not demonstrate any measurable adverse impacts on the area's groundwater or the health of the population ingesting this water.

2. While the information provided in this report delineates the impact of the existing operation of the Whittier Narrows pro-

ject, it does not directly show what impact the increased use of reclaimed water will have on the quality of the groundwater or the health of the individuals consuming the groundwater. It does, however, serve as a baseline study by which impacts of an expansion of the use of reclaimed water can be evaluated.

3. There is a need for continued monitoring and evaluation of the Whittier Narrows project with respect to the trace organic content of the groundwater and replenishment waters. In addition, investigation of the organic compounds responsible for the mutagenicity detected in bacterial tests may be prudent in order to determine whether or not any connection can be made to human health.

RECOMMENDATIONS

1. The existing operation of the Whittier Narrows groundwater replenishment project should continue. Furthermore, because the existing operation has had no adverse impact on either groundwater quality or human health, a closely monitored expansion of the use of reclaimed water should be implemented. The associated monitoring program should be designed to enable early detection of any potential impacts on groundwater quality resulting from the expanded use of reclaimed water for replenishment. Continuation of the expanded program should be conditioned on the finding of no significant degradation of groundwater quality as determined by the monitoring program.

2. The existing monitoring program for percolation source waters and groundwaters should be revised to include some of the organics identified during the course of the study. This program should be reviewed and revised when appropriate as determined from the accumulated data base.

3. Total organic halogen testing should be investigated as a potential surrogate measure for the detection of organic halides in an effort to identify trends that may be associated with groundwater replenishment.

4. Periodic evaluation of the Montebello Forebay population should be conducted in the future in order to examine the possibility that longer periods of exposure to toxic agents, whether of reclaimed water origin or not, might result in an increased incidence of certain diseases. This surveillance is particularly relevant to cancer, since it is widely believed that the induction or latency period between exposure and onset of the clinical disease may be ten to twenty years or more.

5. Restrictions imposed on the volume of reclaimed water percolated should be based on average applications over several years rather than on annual maximums. Likewise, dilution requirements should be regarded from a long-term standpoint.

GOAL

Provide information to the California Department of Health Services that could be used as a basis for developing statewide reclamation criteria for groundwater replenishment.

FINDINGS

1. There was significant variation in effluent and groundwater quality as well as the hydrogeologic conditions of the different sites evaluated by this study.

2. Results from a pilot soil percolation study and literature review showed that percolation did not consistently remove trace organics from reclaimed water.

3. The combination of biological and chemical analytical methods used in this study proved to be valuable for measuring levels of conventional water quality parameters and focusing attention on components that may have significance with regards to long-term carcinogenic risk.

CONCLUSIONS

1. Percolation cannot, in itself, be relied upon as a treatment process for the removal of specific health-significant compounds.

2. Given the numerous variables involved with groundwater replenishment, implementation of new projects or expansion of existing projects should be evaluated on a case-by-case basis.

3. Results from this study provided a basis for assessing the relative impacts on groundwater from the various Whittier Narrows percolation sources and determining the chemical nature of some unknown materials.

RECOMMENDATIONS

1. Methods and results developed by this study provide a basis for evaluating groundwater replenishment projects outside of the Whittier Narrows region. The implication that the exist-

ing replenishment operation has not resulted in a measurable adverse impact on the groundwater of the Montebello Forebay allows the project to be considered a prototype by which other replenishment projects may be compared. The physical and operational aspects of the project that may be used for comparison include wastewater treatment processes, percolation practices, water quality data, and hydrogeologic conditions.

2. For new groundwater replenishment projects under consideration, it should be recognized that water quality monitoring will be necessary for long-term surveillance purposes. In addition, consideration should be given to initiating epidemiologic studies of vital statistics data for the purpose of establishing baseline data for evaluation of health trends in a population exposed to reclaimed water through groundwater replenishment. The costs of water quality monitoring and epidemiologic studies should be incorporated into the economic analysis of proposed projects.

STUDY SUMMARY

Sampling Sites

Within the South Coast Region, four sites were selected for study on the basis of historical or planned reuse (see Figure I-1). The first and most important of these was the Montebello Forebay in Los Angeles County, where groundwater replenishment by surface spreading of reclaimed water has been practiced since 1962. During the twenty years the project has been in operation, over 439,000 AF of disinfected secondary and tertiary effluent have percolated into the Central Basin groundwater system. On an annual basis, reclaimed water currently constitutes about 26,500 AFY or 16 percent of the total inflow including storm water and imported Colorado River and State Project waters. An arbitrary upper limit for reclaimed water of 32,700 AFY has been established based on historical spreading operations. The marketing evaluation conducted for the OLAC Water Reuse Study, concluded that the current level of reclaimed water use be expanded to 50,000 AFY, or approximately 30 percent of the total inflow.

The second site selected for study was the eastern section of the San Fernando Groundwater Basin in Los Angeles County. Current groundwater replenishment is limited to spreading surface runoff, imported water from the Owens Valley, and base flows of the Los Angeles River which traverses the basin. The OLAC Water Reuse Study proposed that approximately 20,000 AFY of reclaimed water be used to augment the existing replenishment operations. This level of reuse would constitute 20 to 25 percent of the safe yield of the basin.

The third site selected was the Anaheim Forebay in Orange County, which is the principal replenishment area of the Santa Ana Groundwater Basin. Replenishment is accomplished by percolation of storm runoff, imported water, and base flows of the Santa Ana River. Some incidental (unplanned) replenish-

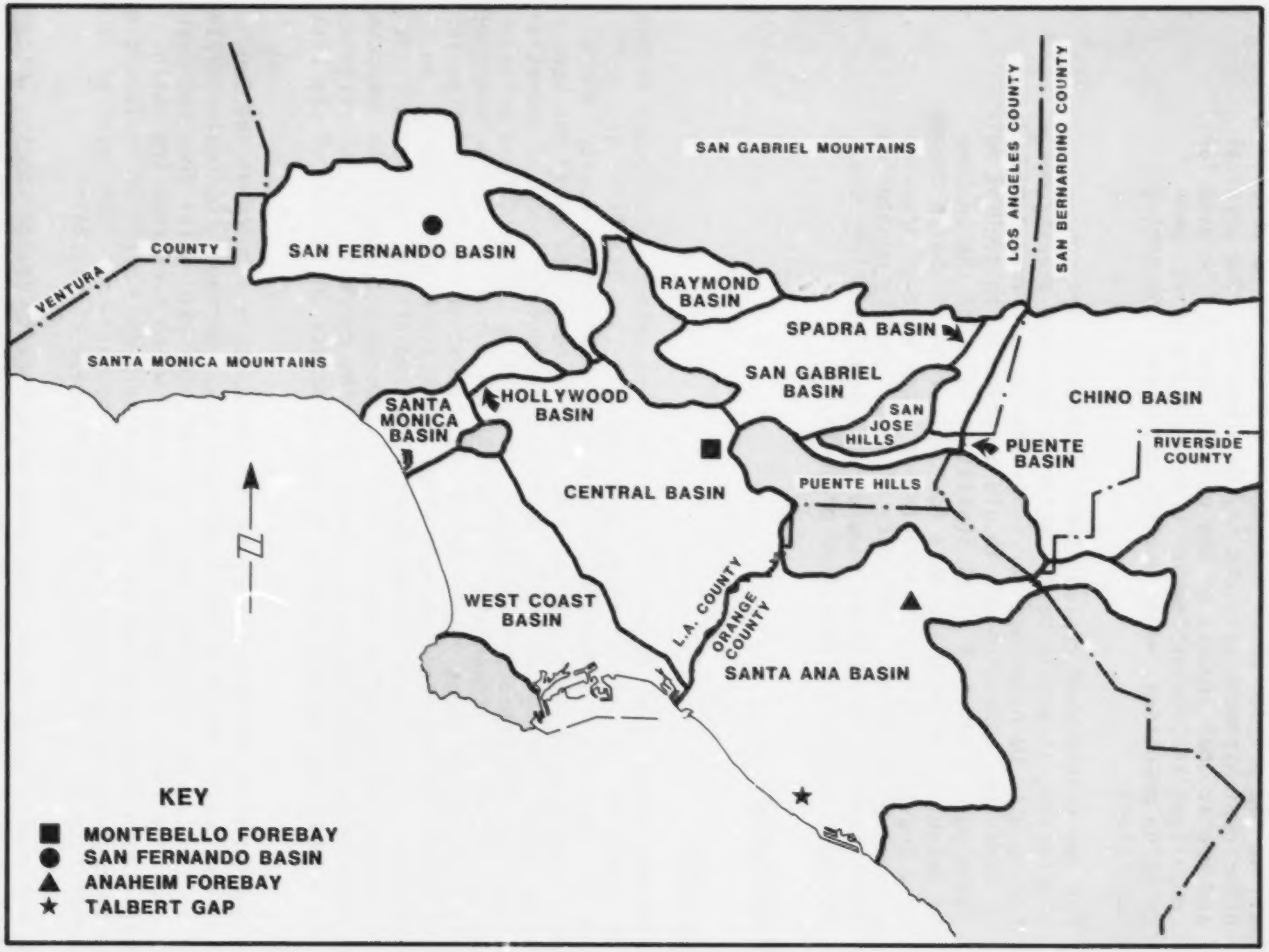

FIGURE I-1 HEALTH EFFECTS STUDY SAMPLING SITES

ment has occurred through upstream discharge of treated wastewater into the Santa Ana River. It has been proposed to augment existing replenishment in the Anaheim Forebay with reclaimed water. The project under consideration would initially provide 12,000 AFY of reclaimed water with an additional 12,000 AFY planned for future expansion. This full scale level of reclaimed water use would represent approximately eight percent of the total input to the groundwater basin.

The final site selected for study was the Talbert Gap, also located in Orange County. It is the site of the Talbert Coastal Barrier Project, which in addition to preventing saltwater intrusion also provides for some groundwater replenishment. The water injected into the intrusion barrier is a blend of native groundwater and advanced waste treated effluent. On an average basis, approximately 11,000 AFY of reclaimed water is injected into the barrier system.

The detailed evaluation of each site differed in terms of emphasis, with the majority of work directed towards the Montebello Forebay. This site had been impacted by groundwater replenishment with reclaimed water for a sufficient period of time to allow for meaningful evaluation of water quality and human health effects. Work conducted for the San Fernando Basin and Anaheim Forebay study sites was designed to provide background information for planned replenishment projects, while work done for the Talbert Gap area was conducted to evaluate the impacts of reclaimed water injection on groundwater quality and to provide data for comparison with other data compiled for the Talbert Barrier Project.

Water Quality Characterizations

Water quality characterizations were conducted for each of the four sampling sites. Groundwater, imported water, reclaimed water, storm water, and dry weather runoff were characterized, as available, in each study area. The parameters selected for evaluation comprised the traditionally monitored minerals, nutrients, and metals, many of which are regulated under primary and secondary drinking water standards. In addition, physical parameters such as pH, color, and turbidity, and bacterial indicators such as coliforms, fecal *streptococci*, and total plate count were measured. Treatment plants and wells in the Montebello Forebay and Anaheim Forebay were characterized for virus in a program separate from the more standard water quality monitoring analyses.

Results obtained from the water quality evaluations demonstrated that the use of reclaimed water for groundwater replenishment in the Montebello Forebay has not adversely impacted the potability of the area's groundwater in terms of inorganic chemical and microbiological contaminants. Reclaimed water from the Los Angeles County Sanitation Districts' San Jose Creek, Whittier Narrows, and Pomona Water Reclamation Plants and imported waters used for replenishment have traditionally met health-related primary drinking water standards and most aesthetics-related secondary standards as has the groundwater impacted by the replenishment operation. Well water concentrations in excess of secondary standards were not attributable to any of the replenishment water supplies; a variable pattern of concentrations above the standards appeared to be a local water quality phenomenon. As for storm water, concentrations of many trace constituents, particularly lead, have historically exceeded specified limits.

No corresponding water quality problems have been observed in the wells, suggesting that dilution and/or soil attenuation have occurred. The only groundwater impact resulting from the replenishment operation has been a fluctuating temporal trend in mineral levels caused by percolation of imported waters.

Virus sampling results indicated that the replenishment operation has not impacted groundwater quality in terms of viral contamination. No viruses were detected in any of the Montebello Forebay groundwater samples or any disinfected tertiary effluents.

Based on these results, it would appear that, in terms of inorganic chemical and microbial constituents, the existing replenishment practice could be expanded without modification. At present, the treatment plants supplying reclaimed water for replenishment routinely produce effluents containing inorganic chemical and microbial constituents at levels that pose no known acute or chronic health threat. There have been concerns expressed over the impacts of plant upsets; i.e., situations in which the treatment facilities are not in full operation and therefore are producing only partially treated water. Contingency procedures have been established for those situations that allow for improperly treated flows to be diverted from the spreading grounds. Moreover, historical records have shown these episodes to be rare; very few plant upsets have occurred during the 20 years that reclaimed water has been used for groundwater replenishment.

As for the San Fernando Basin, results from groundwater sampling have demonstrated that background concentrations of inorganic chemical constituents are in compliance with drinking water standards. Differences were observed between the two well fields monitored in terms of mineral quality. It is speculated that the higher concentrations reported for one of the well fields resulted from the percolation of dry weather runoff in the Los Angeles River which appeared to be high in mineral content.

Reclaimed water sampled for the San Fernando Basin was obtained from the Los Angeles/Glendale Water Reclamation Plant. Effluent from the facility did not typically comply with cadmium requirements for drinking water. This problem, considered to be of industrial origin, may be resolvable through the implementation of more stringent source control measures. Should the reclaimed water to be used for future replenishment in the San Fernando Basin be of similar quality, it will be necessary to determine whether or not it is critical to insure that the heavy metal concentrations in the final effluent routinely comply with maximum contaminant levels prior to replenishment. Experience from the use of storm runoff as a replenishment source in the Montebello Forebay has indicated that no problems have resulted from percolation of a source water that has contained some trace constituents at concentrations above allowable limits. However, it should be recognized that at present there is no control over the quality of storm water entering the basin. The same is not true for reclaimed water. Thus, if the problem can be corrected by source control or operational modifications in existing treatment, then a conservative approach would dictate that the effluent meet standards prior to use.

No data were collected on the virological characteristics of the Los Angeles/Glendale Water Reclamation Plant. In lieu of virus sampling, proper operation of this and similar facilities should insure the production of "essentially virus-free" effluents as verified by the negative virus data obtained for the Montebello Forebay.

Data obtained for the Anaheim Forebay wells were also in compliance with drinking water standards. No viruses were found in any of the chlorinated or unchlorinated well samples. Data obtained for the Orange County advanced waste treatment facility, Water Factory 21, which produces reclaimed water for salt water barrier injection, were in agreement with previously collected data from the facility. Results demonstrated that concentrations of inorganic constituents reliably complied with drinking water standards. No measurable levels of virus were detected in effluent samples. Inorganics data collected for the Talbert Barrier observation wells yielded similar results with no apparent impacts from the injection operation. Production of an effluent similar in quality to that produced by Water Factory 21 (as envisioned for the proposed Anaheim Forebay recharge) should negate any risks for the transmission of harmful agents via surface percolation.

Toxicology and Trace Organics

The complex and largely unknown composition of trace organic chemical residues in wastewater has recently become the major concern related to the use of reclaimed water for groundwater replenishment. Of particular interest is the possible occurrence of long-term or chronic disease (especially cancer and birth defects) in populations ingesting water which might contain organic components having genotoxic effects in humans.

In order to assess possible adverse impacts of reclaimed waters and other percolation source waters on groundwater supplies, an interdisciplinary experimental approach was devised which employed toxicological screening assays for mutagens and chemical separation/identification methods for isolating and characterizing unknown genotoxic compounds. In conjunction with this, all samples were analyzed for a list of target organics which were considered to be priority health concerns and which were not uniformly amenable to detection by the toxicological methods chosen.

Target organic analyses were conducted on multiple samples from all four study areas, while the more detailed toxicology/trace organics work focused primarily on the Montebello Forebay wells and percolation sources tributary to the Forebay. General comparisons of the molecular complexity and organic content were made for various sample types in all four areas. The data suggest that in order of complexity, the samples could be ranked as follows: surface runoff ≥ reclaimed water > imported water > groundwater. The exception to this order was reverse osmosis-treated reclaimed water, which was similar to groundwater in organic content. In addition, it was observed that the general organic complexity of groundwaters appeared to be related to the proximity of the site to industrial operations, i.e., in order of complexity, the groundwater sites could be ranked as follows: San Fernando Basin > Montebello Forebay > Anaheim Forebay ≥ Talbert Barrier.

Results of target organic analyses in the Montebello Forebay suggested that influence from all percolation sources could be seen in the refractory organic content of well waters. Storm water contributed tetrachloroethylene, atrazine, chlorinated phenols, phenylacetic acid, and phthalates; reclaimed water contributed methylene chloride, chloroform, trichloroethylene, tetrachloroethylene, chlorinated phenols, and phthalates; imported water from the Colorado River contributed trihalomethanes and phthalates. In addition to input from percolation sources, the impact on trihalomethane (THM) concentrations in well waters was also influenced by chlorination practices at the wells. Other target compounds were detected, but either the incidence was sporadic or the concentrations too low to identify sources or determine the potential impact of these materials.

Although target organics present in different percolation sources could be detected in Montebello Forebay groundwater, the health impact appeared to be insignificant relative to the EPA's maximum contaminant levels (MCLs), National Academy of Sciences "suggested no adverse response levels" (SNARLs), or State Department of Health Services (DOHS) "action levels." Even when viewed in comparison to the very conservative EPA Water Quality Criteria theoretical cancer risk model, where the analytical methodology has sufficient sensitivity, the average groundwater concentrations of solvents and pesticides were below estimated carcinogenic risk levels.

In the San Fernando Basin, the percolation of dry weather surface runoff (incidental drainage and improper industrial waste disposal) appeared to impact groundwater content of methylene chloride, THMs, tetrachloroethylene, trichloroethylene, chlorinated benzenes, phthalate, atrazine, and simazine. California DOHS "action levels" for trichloroethylene and tetrachloroethylene and the proposed EPA criteria for tetrachloroethylene were exceeded in some well samples, although the National Academy of Sciences SNARLs were not.

Anaheim Forebay wells showed impacts of surface water percolation and incidental discharge of treated wastewater to the Santa Ana River Basin as evidenced by the quantifiable levels of methylene chloride, trichloroethylene, tetrachloroethylene, phthalate, atrazine, and simazine. As observed for the Montebello Forebay wells, chlorination had a discernible effect on the THM content of Anaheim Forebay groundwater. None of the Anaheim Forebay samples exceeded DOHS "action levels," EPA MCLs or NAS SNARLs. Only one well (chlorinated) contained THMs in excess of the EPA proposed criteria.

In the Talbert Barrier observation wells, the probable influence from injection of reclaimed water was detected in terms of methylene chloride, THMs, tetrachloroethylene, toluene, and phthalate. However, none of the observation wells exceeded any of the current contaminant limitations.

In addition to the target organics work, toxicity testing and chemical analyses were performed to isolate and identify other organic compounds of potential health significance which were not included on the target organics list. The approach utilized relied on the Ames test, a short term toxicity test which uses Salmonella bacteria as the test organism to determine the presence or absence of mutagens in a sample. Although the results of the Ames test have no demonstrated correlation to human health, the test is a useful screening tool for detecting the presence of organics capable of causing damage to genetic material (possible carcinogens) in complex organic mixtures.

In a survey of mutagenic potential in 90 sample residues isolated from all four study areas, the presence of mutagenic organics was detected in at least one sample from each source. The level of mutagenicity, or potency, detected in the different sample types was generally in the order: storm runoff > dry weather runoff > reclaimed water > well water ≥ imported water. In more than half of the cases observed, chlorination appeared to increase mutagenicity. No simple correlation was discernible between estimated percent reclaimed water in wells and the observed mutagenic potency of residues isolated from the wells.

Detailed separations and mass spectral characterizations of residues revealed only four known mutagens (fluoranthene, benzo[a]pyrene, N-nitrosomorpholine, and N-nitrosopiperidine) distributed over five of 33 samples evaluated. In no case was the concentration of any of these sufficient to have contributed to the levels of mutagenicity detected.

Selected residues were then qualitatively evaluated to determine the involvement of major compound classes in the mutagenic responses and to determine appropriate chemical detection methods. This research led to chemical derivatizations using the selective reagents silver nitrate and 4-nitrothiophenol in order to determine the presence of compounds belonging to two organic classes: organohalides and epoxides. Many compounds belonging to these two classes are considered to be potent mutagens and a few of the compounds in these groups are known to be animal carcinogens. The organohalides are of particular concern in the water field because they contain chlorinated, iodinated, and brominated compounds which may result from water chlorination processes used in industrial or other water treatment processes.

Results of the chemical derivatizations suggested that one or both of the subject compound classes contributed to the observed mutagenicity. Several samples had more than 100 reactive components containing chlorine, bromine, or iodine functional groups, as well as several reactive compounds inferred to be epoxides. Work completed failed to provide positive identification of any of the major components detected in these experiments. Nevertheless, several major reactive components in the organohalide class were detected in groundwater and percolation sources and, while specific origins of these compounds could not be determined from the information at hand, water chlorination practices in general were implicated.

The results of the toxicology/trace organics study indicate that in terms of target trace organics compounds, the current groundwater replenishment practices in the Montebello Forebay have shown no evidence of significant impacts resulting from the use of reclaimed water. Other findings for reclaimed water, such as exceeding some of the EPA Water Quality Criteria and the presence of organohalides and epoxides, suggest that additional information is needed before the long-term effects resulting from replenishment with all percolation sources can be fully evaluated. The presence of industrial organics in all samples analyzed indicates the susceptibility of and need for the protection of water supplies from improper handling of chemicals. Areas of emphasis should include the development of more stringent surveillance for the disposal of industrial wastes and evaluations of the effects of and possible alternatives to chlorine disinfection.

The presence of large numbers of apparently mutagenic halogenated organics in well water and surface supplies indicates the prudence of further characterization of the molecular nature and biological effects of these compounds. This work will be a necessary step in order to confirm or refute any implicit health significance posed by these materials.

Percolation Study

A field study was performed in order to determine the water quality changes that occur during the percolation of reclaimed water through soils. A test basin was constructed in the Montebello Forebay with particular care taken not to disturb the original soil profile. Soil conditions at the site were roughly characterized as medium-to-fine brown oxidized sand for the initial eight feet of depth with medium-to-coarse gray sand encountered at depths greater than eight feet. The groundwater table was located at a depth of approximately 8 feet. Samples were collected from permanent samplers installed at different depths: three each at depths of 2, 4, and 6 feet, one at 7 feet, and two at 8 feet.

The source of reclaimed water for the percolation study was the Whittier Narrows Water Reclamation Plant. The basin was operated on a uniform flooding/drying schedule which consisted of five days of flooding followed by 16 days of drying. Samples were drawn from the basin on the third day of flooding.

The percolation basin samples were monitored for eleven parameters, including five inorganic constituents (ammonia, nitrite, nitrate, total dissolved solids, and total hardness), two gross organic parameters (chemical oxygen demand and total organic carbon), and four trace organic compounds (methylene chloride, chloroform, trichloroethylene, and tetrachloroethylene).

The most apparent trend discerned from the development of concentration/depth profiles for the inorganic and gross organic constituents was the elevated activity that occurred between the 4-foot and 6-foot monitoring depths. This activity was particularly evident in the profiles for chemical oxygen demand (COD), total dissolved solids, total hardness, and nitrate-nitrogen.

The rapid reduction in the concentration of COD and total organic carbon, combined with the apparent nitrification of ammonia to nitrate, indicated that aerobic biological activity existed to a depth of greater than four feet. The concentration of both total dissolved solids and total hardness increased substantially between the 4- and 6-foot depths. It was hypothesized that the pH reduction, which would accompany both nitrification and the biodegradation of carbonaceous substances, resulted in the dissolution of soil minerals and subsequent increase in TDS and hardness concentrations.

Methylene chloride displayed the most substantial concentration reduction of the trace organic compounds monitored. The average influent concentration was reduced almost 90 percent to an average of 1.9 μg/L at a depth of eight feet. Chloroform and tetrachloroethylene showed less dramatic but statistically significant removals of 52 percent and 56 percent, respectively. The concentration of trichloroethylene was not reduced during percolation through the first eight feet of soil.

Adsorption, volatilization, and biodegradation were initially identified as potential trace organic removal mechanisms. Each was then examined in an effort to determine the operative treatment mechanism in the percolation basin.

Since the adsorption capacity of a soil is finite, it was necessary to determine whether or not the soil adsorption sites had been saturated during the percolation study. To this end, an empirical equation was utilized to estimate the relative retention time of each compound as it traveled through the soil. The empirical equation, which was developed for small concentrations of organic compounds, correlates a compound's octanol/water partition coefficient with its relative adsorptive affinity in a specific soil. Based on this equation, it was estimated that the capacity of the basin to adsorb methylene chloride, chloroform, and trichloroethylene was completely utilized during the basin conditioning process (five spreading cycles) and the capacity to adsorb tetrachloroethylene was exhausted shortly thereafter. Consequently, it was concluded that adsorption alone could not account for the trace organic compound removals detected in the percolation basin.

In a groundwater recharge operation, volatilization would be expected to occur in the ponded effluent or within the first few inches of soil. Judging from the limited trace organic compound removals detected between the basin influent and the 2-foot depth, volatilization did not appear to be a significant treatment mechanism during effluent percolation.

It was presumptively concluded that biodegradation, perhaps aided by the temporary retention of organics on adsorption sites, was the primary mechanism for the removal of the trace organic compounds. This conclusion was based upon three independent observations. First, there was no removal of trichloroethylene within the top eight feet of the test basin. If adsorption or volatilization was the operative treatment mechanism in the removal of methylene chloride and chloroform, then trichloroethylene should also have been removed from the percolate since it is theoretically of equal or greater susceptibility to these physical treatment mechanisms. Second, the concentration/depth profiles for inorganic compounds and gross organic parameters indicated that the soil environment was suitable for aerobic biodegradation of trace organic compounds. Finally, the literature indicated the occurrence of substantial biodegradation of chloroform and other trihalomethanes, but insignificant biodegradation of trichloroethylene. All three observations implicated biodegradation to be the primary mechanism responsible for the trace organic compound removals detected in this study.

The application of the results of the percolation study to full-scale groundwater replenishment must take into consideration the specific site conditions of the test basin and the proposed spreading grounds. Soil characteristics, replenishment water quality, and basin operation are all critical in determining the effectiveness of soil percolation as a treatment process. Furthermore, the blending of several source waters could serve to dilute the concentration of critical contaminants in each. The optimum dilution ratio would be based upon the mass contribution of one or more critical constituents to the groundwater system by each replenishment water supply after percolation through the soil strata. Accordingly, the quality of non-reclaimed water supplies is as important as the quality of reclaimed water supplies in determining the impact of groundwater replenishment. Therefore, the development of criteria for the use of reclaimed water for groundwater replenishment must take into consideration the quality and quantity of all source waters to be used in the operation.

Development of Population Exposure Data for Epidemiology Study

In order to effectively assess the impact of groundwater replenishment with reclaimed water, it was necessary to determine the levels of reclaimed water contained in the domestic supplies of the exposed population. The level of exposure depended on 1) the proportion of groundwater making up the total supply and 2) the amount of reclaimed water contained in the groundwater.

The methodology used to estimate the percentage of reclaimed water contained in Montebello Forebay groundwater relied on an empirical model which used sulfate as the tracer of groundwater movement. The model was based on the fact that the sulfate concentration of Colorado River water, a replenishment source since 1954, was substantially greater than the sulfate concentrations of storm water, reclaimed water, and groundwater. Sulfate was considered to be a conservative material not likely to be affected by either vertical or horizontal movement through soil. Observations of the changes in sulfate concentrations in Montebello Forebay wells over time paired with the historical proportions of replenishment waters spread each year allowed for charting the movement of Colorado River water through the groundwater basin. This information was in turn used to simulate the behavior of the reclaimed water based on the premise that the two types of water moved at the same rate. Specifically, calculations were performed to estimate the annual percentages of reclaimed water pumped from individual wells operated by the 32 water purveyors serving the Montebello Forebay area.

Because not all of the purveyors used groundwater as their only source of supply, it was necessary to determine the historical water delivery characteristics of each purveyor, including the delineation of service area boundaries, number of residential service connections, water sources, and production levels. Final results of the investigation provided estimates of the annual percentages of Montebello Forebay groundwater making up the total supply served to each of the water systems. Coordinating this information with estimates of reclaimed water in the groundwater system, exposure data were produced that defined the percentage of reclaimed water contained in each purveyor's total water supply. On an annual basis, these estimates ranged from zero to 23 percent, with a long-term average (1962 through 1977) ranging from zero to 11 percent.

The reclaimed water exposure estimates were used to segregate areas of high and low exposure as the basis of the epidemiological comparisons. The low reclaimed water exposure area was defined as those water districts that supplied reclaimed water for at least one year prior to 1970, but in no year prior to 1970 supplied greater than four percent reclaimed water, while the high reclaimed water exposure area was defined as those districts that supplied water containing five percent or more reclaimed water for one or more years prior to 1970. Montebello Forebay communities not exposed to reclaimed water because they did not receive groundwater or the groundwater they received did not contain reclaimed water, were defined as the central control area. A second control area to the northwest of the study area was included to expand the population base studied. This area was chosen because its water supplies did not contain reclaimed water and because the demographic and socioeconomic characteristics of its residents were similar to those of Montebello Forebay residents. At the time of the 1970 U.S. Census, nearly 1.2 million people resided in the overall study area with some 478,000 persons in the high and low exposure areas and 677,000 persons living in the two control areas.

Epidemiology

The University of California at Los Angeles School of Public Health was subcontracted to conduct a multi-stage epidemiologic investigation regarding the health effects of groundwater replenishment in the Montebello Forebay study area. The epidemiologic monitoring activities were divided over time into three temporal phases: 1969-71, 1972-78, and 1979-80. Health parameters evaluated in these ecologic analyses included mortality patterns (death from all causes, heart disease, stroke, and cancer), cancer incidence, infant and neonatal mortality patterns, birth outcome patterns (low birth weight and congenital malformations), and infectious diseases. Also included in the investigation, was a household survey of women, conducted in 1981, which compared the general health status of women residing in the high reclaimed water area to that of women residing in the central control area and a computer simulation analysis which modeled the theoretical relationship between exposure to contaminants in drinking water and measurable health outcomes based on the characteristics of the study population.

Based on the results from the ecologic analyses, there was no association between the 20 health conditions evaluated and residences in the reclaimed water area. Evidence of a potential association between death due to rectal cancer and exposure to reclaimed water based on the analyses of the 1969-71 and 1972-78 data sets, was not substantiated by the evaluations of the 1979-80 data. In fact, the most sensitive indicator evaluated--the onset of rectal cancer cases nearly two decades after exposure was initiated--shows the trend to be just the opposite, with the highest rate occurring in the control areas and the lowest rates in the reclaimed water areas.

It should be noted that the effects of such confounding variables as age, sex, birth weight, and when possible, race ethnicity were controlled in the ecologic analyses. Unfortunately, it was not possible to control other potential confounders such as smoking behavior, alcohol and drug use, dietary practices, bottled water consumption, mobility, marital status, employment status, or occupation, each of which might affect the inherent risk of the individual. To further clarify the actual level of exposure and the effects of confounding factors and to assess their effect on other more subtle health outcomes, a household survey was conducted among women in the exposed and control areas. Health parameters evaluated in the survey included information on adverse reproductive outcomes such as miscarriages and spontaneous abortions and on general indicators of functional impairment such as restricted-activity days, hospital-bed days, and (home) bed disability days.

Simple comparisons between all women in the two study areas demonstrated that there were no significant differences in any of the measured health indices. Other analyses attempted to address the issue of exposure to reclaimed water by comparing women who consumed tap water in the exposed area with women who consumed tap water in the control area (since approximately 22 percent of the women surveyed reported drinking only bottled water). The analyses were further restricted by comparing subgroups of women in the two areas who had lived at their present address for five years or longer. Again, there was no significant difference between the two groups in any of the measured health outcomes. Similar results were obtained when controlling for the confounding effects of age, level of education, employment status, race ethnicity, smoking behavior, and alcohol consumption as well as when limiting the analyses to those women who consumed tap water and who had lived at the same address for at least five years. In general, the level of health observed for the surveyed women tended to be comparable to those reported in other surveys using similar questions lending validity to the accuracy of the survey.

To provide additional insight into the investigations, a computer simulation model was employed to replicate the study population and determine the theoretical effects, based on animal models, of exposure to various contaminants. Outcomes of four diseases were tested in the simulation studies: cancer at all sites, cancer of the rectum, cancer of the liver, and congenital malformations. Four contaminants, dinitrotoluene, heptachlor, polychlorinated biphenyls, and phthalate esters, were assumed to be present in the water of the modeled population. Given the water consumption levels, the migration habits of the people living in the study area and toxicology data for the four compounds, the model estimated the effects these contaminants would individually have on the health status of the exposed population. The results of the simulation study suggested that, in the face of exposure to a particular highly toxic waterborne contaminant of potency similar to the model compounds, a statistically significant increase in the rate of cancer or congenital malformations above the background rate, could not be detected in the reclaimed water community, even up to 24 years following exposure.

Based on the results from all phases of work, available epidemiologic evidence provided no indication that the use of reclaimed water for groundwater replenishment has had a noticeable harmful effect on the population ingesting the water. The completed evaluations of 20 health conditions showed no measurable relationship between exposure to reclaimed water and disease. Furthermore, results of the household survey in 1981 which controlled for such confounding effects as smoking, alcohol consumption, bottled water usage, and length of residence yielded no evidence that exposure to reclaimed water had an effect on levels of adverse reproductive outcomes or on general health indicators. While zero risk can never be insured, based on these findings, it is reasonable to assume that the disease risk attributed to the consumption of water containing reclaimed water has been minimal to non-existent for persons residing in the Montebello Forebay.

CHAPTER II

INTRODUCTION

GENERAL BACKGROUND

Southern California, like many semi-arid regions of the United States, does not receive sufficient water from local sources to support the considerable population of the area. This condition is particularly true for the Orange and Los Angeles Counties Metropolitan area where almost two-thirds of the water supply is imported through three aqueducts that extend between 200 and 500 miles from the point of use. The three systems illustrated in Figure II-1 are 1) the Los Angeles Aqueduct which brings 573,000 acre-feet/year (AFY) of water from the Owens Valley and Mono Basin on the eastern slopes of the Sierra Nevada Mountains to Los Angeles, 2) the Colorado River Aqueduct which brings 750,000 AFY of Colorado River Water from Arizona to the Los Angeles area, and 3) the California Aqueduct which as part of the State Water Project, brings northern California water to Los Angeles.

The remainder of the area's supply is derived from local groundwater basins which are illustrated in Figure II-2. In the past, groundwater extractions have exceeded the natural replenishment afforded by percolation of storm runoff. By the 1950s, this practice caused a serious overdraft condition which allowed for the intrusion of saline ocean water into potable aquifers. To counteract the overdraft, groundwater extractions were adjudicated and local agencies implemented artificial groundwater replenishment programs. Recharge has occurred by surface percolation of blends of captured storm water, imported water and in one case treated wastewater (reclaimed water) in unlined river channels or specially constructed spreading basins. Sea water intrusion has been prevented by injecting fresh water underground through a series of barrier wells aligned parallel to the coastline. The injected water not only has prevented intrusion, but has also supplemented native groundwater. With the exception of one project which utilizes reclaimed water, barrier projects have injected imported water.

There is considerable uncertainty whether water supplies will be sufficient for future water needs in Southern California. Population growth projections (II-1) have indicated that water demands will increase by 16-29 percent over the next 30 years. Yet, at the same time, the future water delivery capability of the region's aqueduct systems will be subject to reductions due to legal, political and climatic factors. By 1985, entitlements to water from the Colorado River will be reduced to 550,000 AFY when the Central Arizona Project becomes operational providing supplies to Phoenix and eventually Tucson. Current litigation associated with the Los Angeles Aqueduct could reduce area deliveries by at least another 100,000 AFY. Political opposition to construction of new storage and delivery facilities for the State Water Project, which are needed to supply contracted entitlements to the area, will likely impede expansion of this system. Compounding all of these situations is the likelihood of cyclical droughts (such as experienced in 1976-77) which unconditionally will reduce

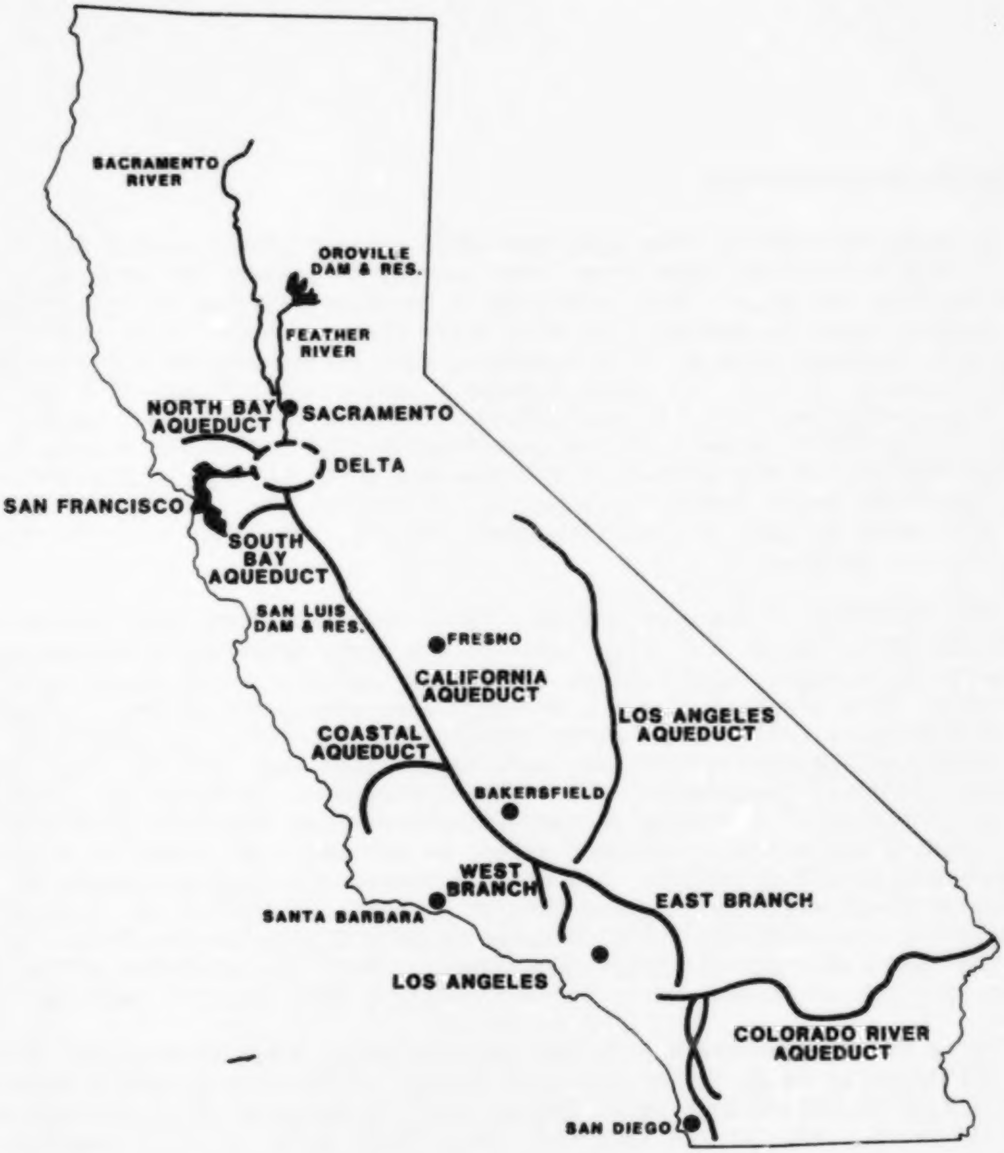

FIGURE II-1
AQUEDUCTS SERVING SOUTHERN CALIFORNIA

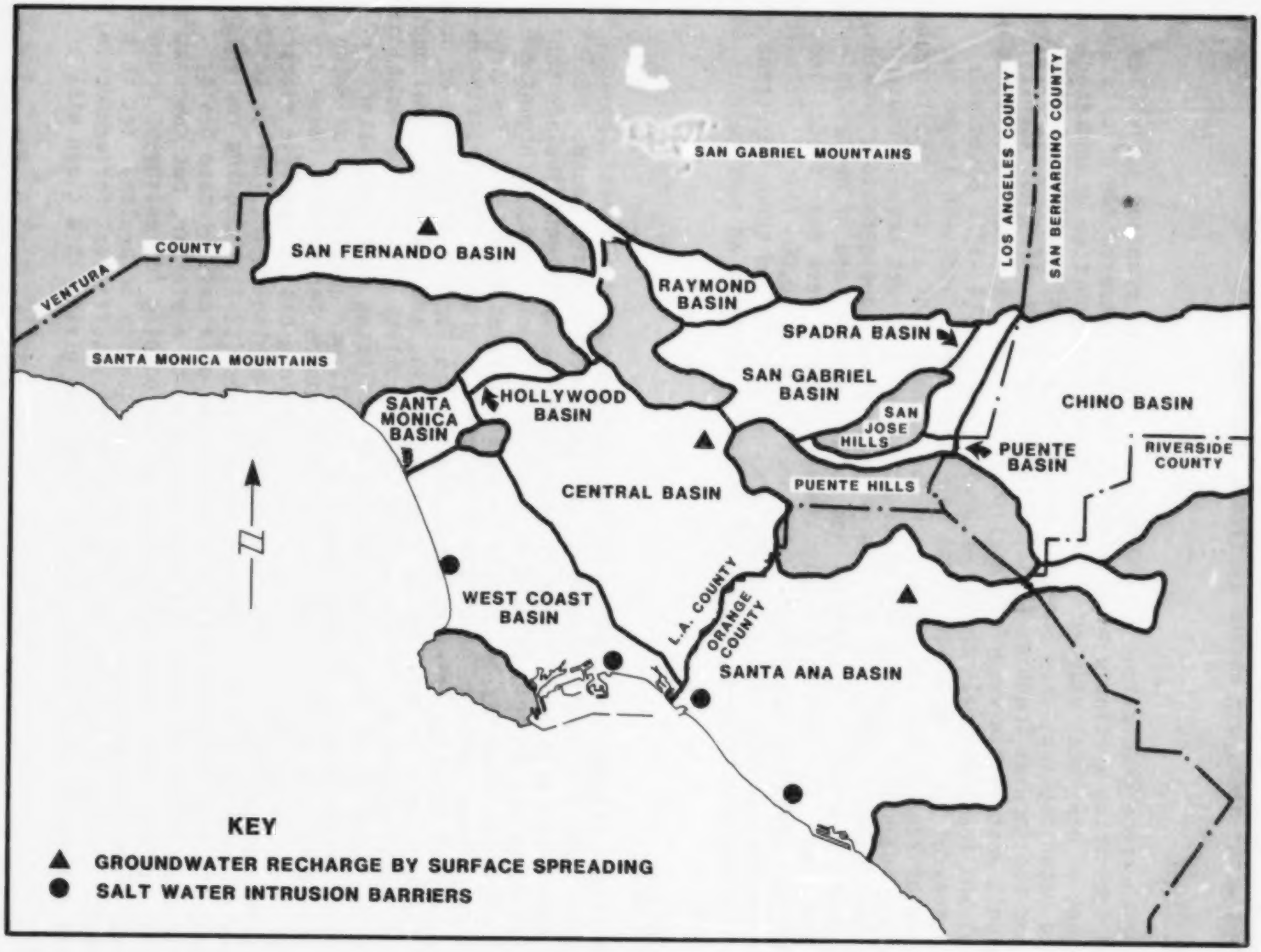

FIGURE II-2 LOS ANGELES COASTAL PLAIN GROUNDWATER BASINS

imported deliveries. Although the resolution of these issues and their effects on the area's water supplies are uncertain, it has been predicted that by the late 1980s water needs may exceed available supplies.

The OLAC Study

Water shortage predictions have stimulated regional planning activities aimed at optimizing available water supplies through conservation efforts and development of new local sources of supply through conjunctive groundwater usage and water reclamation. Foremost among these planning efforts is the Orange and Los Angeles Counties (OLAC) Water Reuse Study which has identified the region's most viable water reclamation projects and has developed a regional financial and institutional scheme for their inception (II-1). Based on a market survey of the area, 34 projects have been identified with a combined capability of 226,000 AFY including such non-potable uses as crop and landscape irrigation, industrial cooling and processing, and indirect potable reuse by groundwater replenishment. Of all the projects under consideration, groundwater replenishment represents the largest and most economical use of reclaimed water within the area. Six potential replenishment projects have been identified; three surface spreading operations which would provide 60,000 AFY of reclaimed water at an average unit cost (1980 dollars) of $231/AF and three injection projects which would utilize 48,400 AFY of reclaimed water at an average unit cost of $507/AF.

Health Issues

The single largest constraint limiting implementation of these projects is the concern over the health impacts of indirect potable water reuse. Health issues associated with water reuse by groundwater replenishment include the potential acute and chronic effects of trace metals, minerals, pathogens and organic compounds that may be present in water supplies impacted by recharge activities. These concerns have been heightened by growing uncertainties over the adequacy of existing drinking water regulations for the protection of human health (particularly in the area of trace organics), and the traditional application of these standards for evaluating the potability of water reclamation. Because the question of the health effects of utilizing reclaimed water for groundwater replenishment is one element of the larger question of drinking water and health and because health related standards for potable reuse are in a state of flux, it is not surprising, that California has no specific operational requirements or quality criteria for groundwater replenishment similar to the existing reclamation criteria for non-potable uses (II-2). Ongoing replenishment projects have been evaluated and anthorized on a case-by-case basis; authorization of new projects has been relegated to a similar, but somewhat more equivocal status. Available information on the ongoing replenishment projects has never shown any evidence of impaired water quality or health. Yet this information (based on current thinking) is still insufficient for conducting a rigorous evaluation of indirect potable reuse and giving it a clean bill of health.

Recognition of the need for more scientific data was notably demonstrated in 1976 with the publication of the final recommendations of a state sponsored "blue ribbon" panel of experts (II-3) charged with the dual task of 1) determining the availability and significance of information related to the health aspects of groundwater replenishment that could be used to develop statewide reclamation criteria, and 2) devising means for developing new information if warranted. The Panel unequivocally concluded that more information was needed and recommended a series of research tasks be conducted for an established, well engineered groundwater replenishment operation to provide the needed data base.

The groundwater replenishment projects in Los Angeles and Orange Counties provided an excellent opportunity to implement the Panel's research recommendations. These were subsequently incorporated into a comprehensive work plan for the Health Effects Study (II-4). Work efforts on the study officially began in November 1978.

STUDY SITES

Within the South Coast Region, four sites (see Figure II-3) were selected for study on the basis of historical or planned reuse by groundwater replenishment:

- The Montebello Forebay area of the Central Groundwater Basin in Los Angeles County, where replenishment of groundwater by surface spreading has been practiced since 1962. Expansion of this reuse project is planned for post 1991. Because of its historical significance, this area was chosen as the focal point of the study.
- The eastern section of the San Fernando Groundwater Basin in Los Angeles County where surface spreading of reclaimed water is slated to begin post 1991.
- The Anaheim Forebay area of the Santa Ana Groundwater Basin in Orange County where surface spreading of reclaimed water is slated to begin post 1991.
- The Talbert Gap area of the Santa Ana Groundwater Basin in Orange County where injection of reclaimed water for prevention of saline water intrusion has been practiced since 1976.

General descriptions for each study site are presented in the following text.

Montebello Forebay

The Central Basin is the largest groundwater basin in the Coastal Plain, having an adjudicated pumping limitation of 217,000 AFY and an estimated usable storage capacity of 780,000 AF. Natural replenishment occurs in the unconfined aquifers of the Los Angeles and Montebello Forebay areas. Historically, the Los Angeles Forebay (south central Los Angeles vicinity) was the replenishment location for the Los Angeles River; however, urban development has greatly

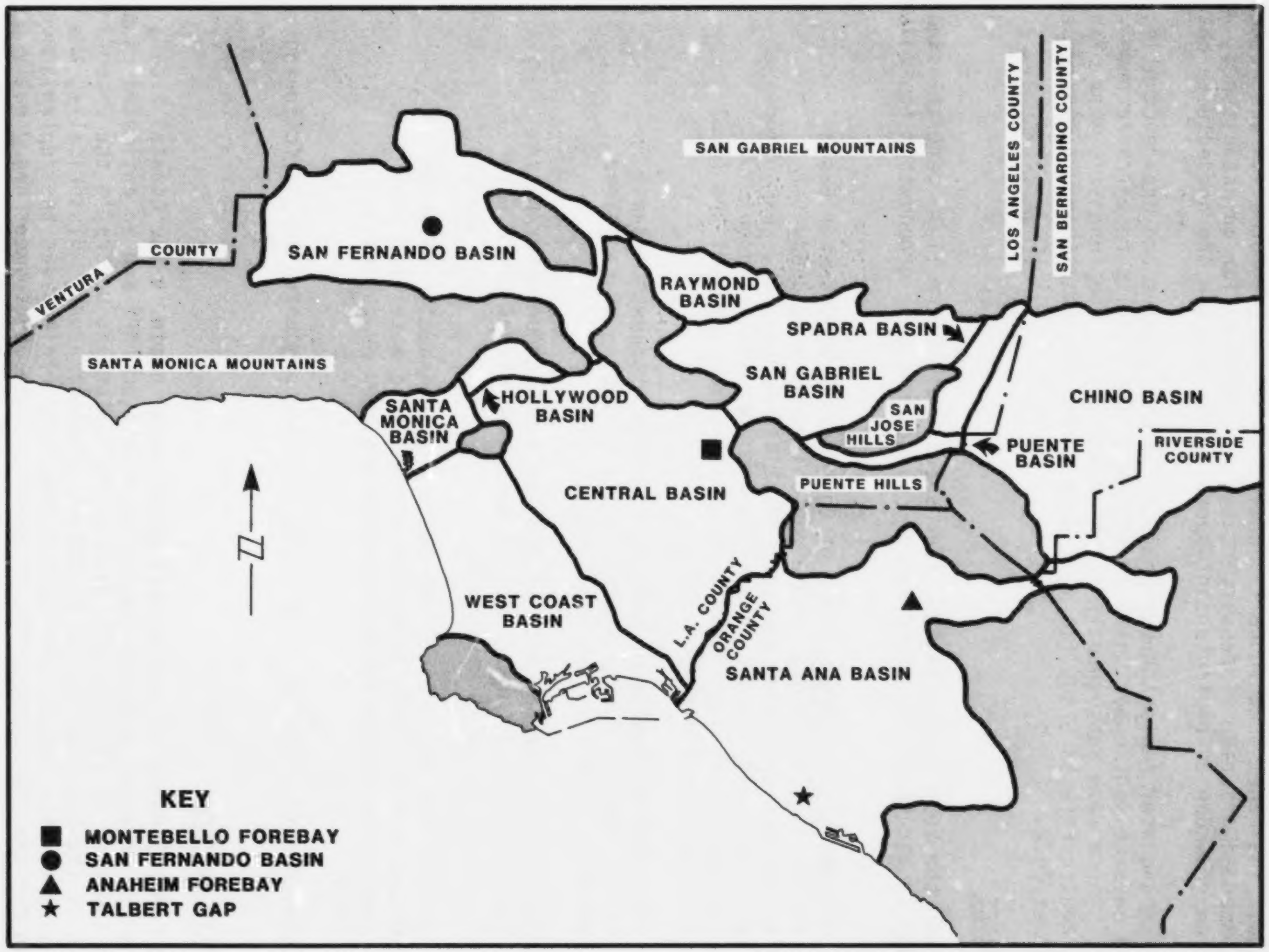

FIGURE II-3 HEALTH EFFECTS STUDY SAMPLING SITES

reduced the area's replenishment potential. Consequently, the Montebello Forebay is now the primary replenishment location (see Figure II-4).

The Montebello Forebay is located in the northerly portion of the Central Basin immediately below the Whittier Narrows. The area is traversed by the San Gabriel River and by the Rio Hondo (tributary to the Los Angeles River) which convey runoff from the San Gabriel Valley through the Whittier Narrows to the Coastal Plain. Consequently, the Montebello Forebay is overlain by water bearing river deposit sediments which vary in age from recent to early Pleistocene and extend to a maximum depth of about 1,050 feet (900 feet below sea level).

Groundwater movement is generally in a southwesterly direction, flowing from the San Gabriel Basin (to the north) through the Whittier Narrows into the Central Basin. The geologic characteristics of the Whittier Narrows are such that the passing groundwater is forced upwards and during certain times of the year becomes surface or "rising" water. From the Whittier Narrows, south, the groundwater table gradually begins to decline.

Within the Montebello Forebay proper, there is a significant degree of hydraulic continuity between the uppermost Gaspur Aquifer and the successive underlying Exposition - Artesia Aquifer, Gardena-Gage Aquifer, Hollydale Aquifer, Jefferson Aquifer, and Lynwood Aquifer. Hydraulic continuity between these aquifers and the deeper Silverado and Sunnyside Aquifers is generally limited to relatively small areas near the Whittier Narrows.

Replenishment of Groundwater Supplies. Under natural conditions, groundwater in the Montebello Forebay was replenished by 1) percolation from the channels of the San Gabriel River and Rio Hondo and other streams crossing the area; flow in these streams consisted of storm runoff and rising water from the San Gabriel Basin, 2) subsurface flow from the San Gabriel Valley, and 3) percolation of local precipitation.

As part of its many responsibilities, the Los Angeles County Flood Control District has implemented an artificial replenishment program in the Montebello Forebay to augment recharge that occurs naturally. This program combines both the elements of water conservation and water resources management. First, the Flood Control District has constructed surface storage facilities for storm runoff in the mountainous area tributary to the San Gabriel River and Rio Hondo. Captured storm flows, which otherwise would have been wasted to the ocean, are released at rates compatible with the downstream percolation capacity. Second, the Flood Control District has constructed special spreading areas designed to increase the indigenous percolation capacity. Specifically, this has consisted of both modifications to the San Gabriel River Channel and construction of offstream spreading basins adjacent to the Rio Hondo and San Gabriel River.

The Rio Hondo spreading facility, as illustrated in Figure II-4, is the largest replenishment location, having a total of 455 wetted acres available for spreading. The San Gabriel River spreading basins have some 101 wetted acres available for replenishment with an additional 133 acres of river bottom which can be used when needed. The Rio Hondo and San Gabriel River spreading grounds are subdivided into individual basins which range in size from four to twenty acres.

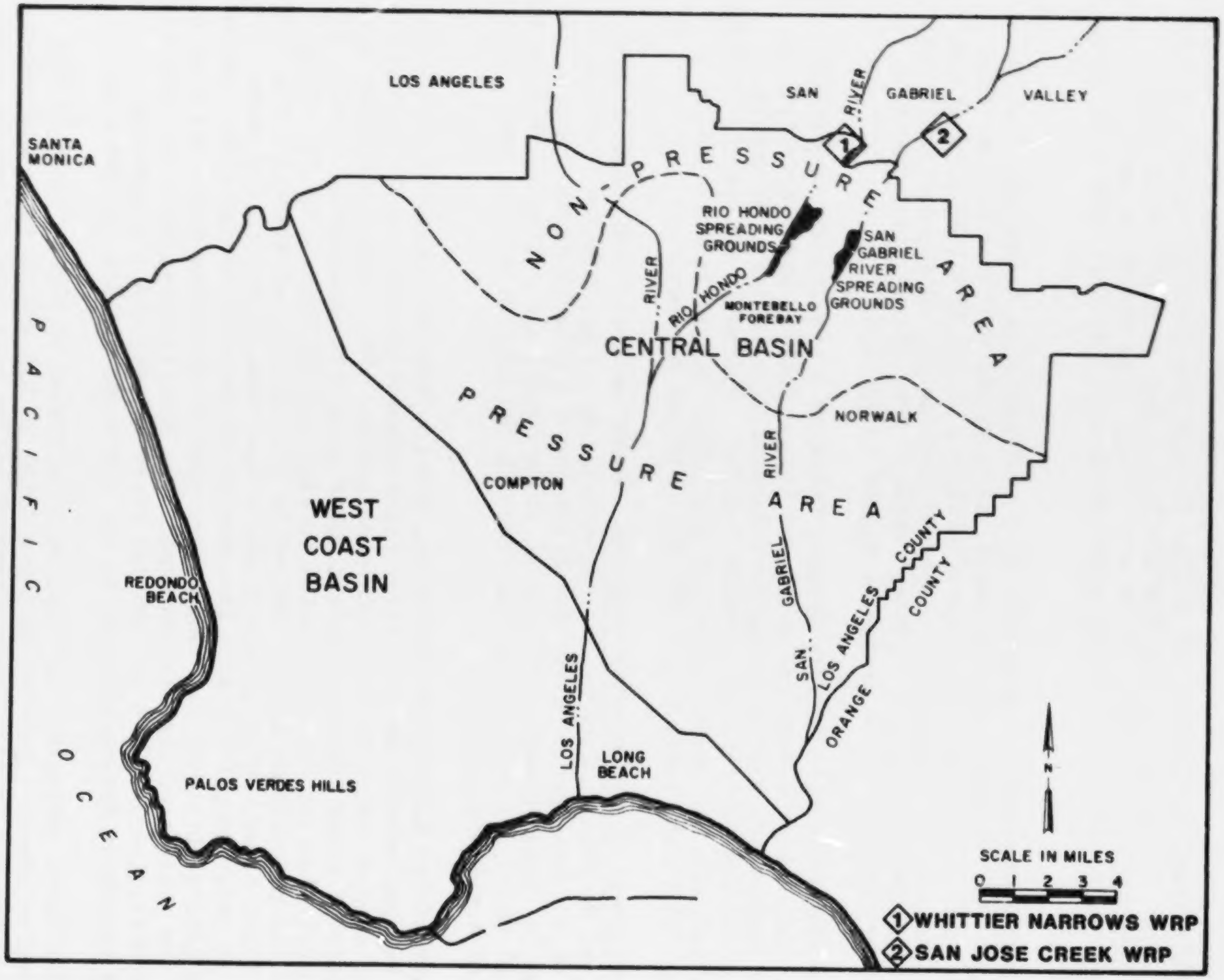

FIGURE II-4 MONTEBELLO FOREBAY GROUNDWATER RECHARGE FACILITIES

Under normal operating conditions, batteries of the basins are rotated through a 21 day cycle consisting of 1) a seven day flooding period during which the basins are filled to maintain a constant four foot depth, 2) a seven day draining period during which the flow to the basins is terminated and the basins are allowed to drain, and 3) a seven day drying period during which the basins are allowed to thoroughly dry out. This wetting/drying operation serves several purposes, including maintenance of aerobic conditions in the upper soil strata and vector control. Infiltration rates during the flooding period average about 2 ft/day. The capacity of the spreading grounds during normal operation is about 300 cfs. During winter storm periods, when all the basins are in use, the capacity increases to 950 cfs.

The available percolation capacity of the replenishment facilities is utilized only during a small portion of the year for spreading storm runoff, thus allowing for replenishment by water from other sources. This practice first began in the 1950s with the purchase of Colorado River water imported by the Metropolitan Water District of Southern California (MWD). Funds used to purchase the water are currently obtained from groundwater pumping assessments levied by the Central and West Basin Water Replenishment District, the managing agency for the groundwater basins of the Los Angeles Coastal Plain. In 1974-75, State Project water was purchased as a supplemental replenishment source. Since that time the water delivered for spreading has been made up of varying proportions of Colorado River water and State Project water (see Table II-1), depending upon the availability of supplies from the Metropolitan Water District.

The other water source used for replenishment in the Montebello Forebay has been reclaimed water purchased from the Los Angeles County Sanitation Districts. Reclaimed water was first made available in 1962 following the completion of the Whittier Narrows Water Reclamation Plant (WRP) and later in 1973 when the San Jose Creek WRP was placed in service. Reclaimed water has also been incidentally supplied by the Districts' Pomona WRP. Effluent from the Pomona plant which is not put to beneficial use is discharged into San Jose Creek, a tributary of the San Gabriel River, and ultimately becomes a source of recharge for the Montebello Forebay. As the Pomona effluent becomes fully utilized for irrigation and industrial applications within the Pomona area, this replenishment source is expected to diminish.

Through 1977-78, the reclaimed water used for replenishment was disinfected activated sludge secondary effluent. Since that time all three treatment plants have been upgraded to include either dual media filtration (Whittier Narrows and San Jose Creek WRPs) or activated carbon filtration (Pomona WRP) prior to disinfection. The final effluents produced by each treatment facility comply with primary drinking water standards and meet average coliform and turbidity requirements of <2.2 MPN/100mL and <2 T.U., respectively (II-2).

The current policy of the Replenishment District is to spread an annual amount of reclaimed water not to exceed the historical use. Including the incidental recharge from the Pomona WRP, the total maximum use has been 32,700 AFY. All of the effluent from the Whittier Narrows Plant (13,000 AFY) is used for replenishment except for a small portion lost to the ocean during storms. Deliveries of reclaimed water from the San Jose Creek WRP have ranged from 6,000

TABLE II-1
TOTAL INFLOWS TO THE MONTEBELLO FOREBAY
(THOUSANDS OF ACRE-FEET)

Water Year	Reclaimed Water				Imported Water			Local Water					Total
	Whittier Narrows WRP	San Jose WRP	Pomona WRP	Subtotal	Colorado River Water	State Project Water	Subtotal	Subsurface Inflow	Rising Water	Storm Inflow	Local Precipitation	Subtotal	
1960-61					121		121	26	6	5	11	48	169
1961-62	1			1	180		180	23	11	34	23	91	272
1962-63	12			12	68		68	21	7	9	12	49	129
1963-64	13			13	86		86	21	3	11	11	46	145
1964-65	15			15	136		136	19	2	15	13	49	200
1965-66	15			15	102		102	17	6	41	20	84	201
1966-67	16			16	67		67	17	14	47	22	100	183
1967-68	18		6	24	79		79	21	17	16	12	66	169
1968-69	14		6	20	17		17	24	26	88	26	164	201
1969-70	17		9	26	61		61	24	23	21	11	79	166
1970-71	19		8	27	63		63	23	14	22	12	71	161
1971-72	18		8	26	30		30	24	6	18	11	59	115
1972-73	14	8	8	30	80		80	26	8	30	22	86	196
1973-74	13	8	6	27	80		80	27	7	26	14	74	181
1974-75	15	7	5	27	11	56	67	26	4	18	13	61	155
1975-76	12	9	5	26	1	34	35	28	1	18	5	52	113
1976-77	10	13	1	24	12	14	26	32	0	19	11	62	112
1977-78	13	6	3	22	0	35	35	31	3	108	36	178	235
1978-79	11	12	6	29	0	59	59	27	8	56	24	115	203
1979-80	14	10	4	28	0	19	19	25	12	76	26	139	186
1980-81	11	15	5	31	51	13	64	27	9	34	11	81	176
				439			1,475					1,754	3,668

to 15,000 AFY which are substantially less than the total plant production capability of 70,000 AFY. Reclaimed water from the San Jose Creek WRP is not accepted when adequate amounts of local water are unavailable for dilution, when large amounts of imported water or local water are being spread, when its mineral content (TDS) exceeds 700 mg/L, or when continued spreading would cause the total reclaimed water use to exceed historical limits.

Since 1972-73 when all three treatment plants began contributing reclaimed water for groundwater replenishment, the annual amount of reclaimed water entering the Montebello Forebay has averaged about 27,000 AFY or 16 percent of the total inflow to the basin. During the 20 year period following the completion of the Whittier Narrows WRP, over 439,000 AF of reclaimed water have infiltrated into the Forebay, representing 12 percent of the total water input. The OLAC Study has proposed that the current level of use of reclaimed water for groundwater replenishment be expanded to a maximum of 50,000 AFY, or approximately 30 percent of the total inflow to the Montebello Forebay.

San Fernando Basin

The San Fernando Valley, which lies in the northwest corner of Los Angeles County, is one of the principal drainage areas of the Los Angeles River and its northerly tributaries. The San Fernando Basin is the largest of four groundwater basins in the valley, having a calculated safe yield of 90,680 AFY and an estimated storage capacity of 3.2 million AF (see Figure II-5). Natural geologic processes have resulted in the deposition of coarser sediments in the eastern half of the basin, which have higher permeability and better water yields than the finer sediments found in the western portion. The favorable geologic conditions have lead to the significant development of groundwater resources (wells and recharge facilities) in that area.

Annual groundwater extraction in the basin is limited to the native safe yield plus return flows from imported water used for replenishment. Based on a decision by the State Supreme Court, the City of Los Angeles has a Pueblo Right to pump all groundwater resulting from precipitation in the entire Los Angeles River watershed (43,660 AFY). The cities of Los Angeles, Burbank, Glendale, and San Fernando are entitled to extract the amount of delivered imported water which percolates into the San Fernando Basin. As an example, the annual pumping allotments for water year 1979-80 were divided as follows: Los Angeles (81,800 AFY), Burbank (4,800 AFY), Glendale (4,200 AFY) and San Fernando (0 AFY). A key point in the Supreme Court decision is, that these cities may spread imported and reclaimed waters in the San Fernando Basin and recover an equivalent amount of groundwater over and above their annual pumping allowance. This conceptually allows for cyclic storage of water in the groundwater basin during wet years which could be withdrawn for use during dry years.

Groundwater Replenishment. There are six spreading ground areas in the San Fernando Basin; four of these are operated by the County Flood Control District (the Branford, Hansen, Lopez, and Pacoima spreading grounds) and two by the City of Los Angeles Department of Water and Power (Tujunga and Headworks spreading grounds). The Flood Control District facilities are used to percolate storm runoff, averaging approximately 15,500 AFY. The city facilities are used, for the most part, to spread storm water, water imported from the Owens Valley and

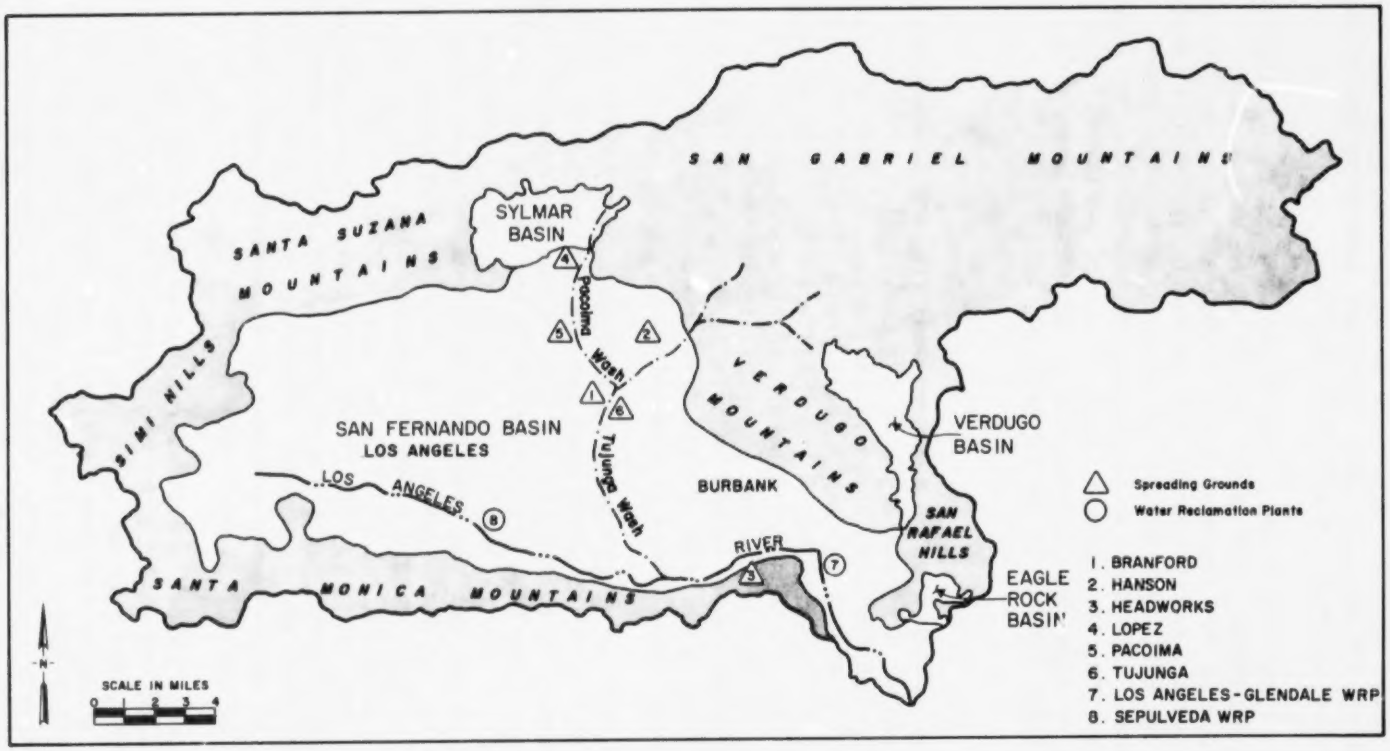

FIGURE II-5 SAN FERNANDO BASIN GROUNDWATER RECHARGE FACILITIES

base flow in the Los Angeles River. On an annual basis, approximately 11,000 AFY of water are spread. Because the base flows of the Los Angeles River contain a proportion of industrial discharges, some incidental recharge of wastewater occurs in the basin. However, the actual proportion of reuse is very small, since the percolation of base flows of the Los Angeles River represents only about six percent of the basin's safe yield.

Analyses performed by the Department of Water and Power indicate that the San Fernando Basin has about 500,000 AF of additional useable storage capacity. The Department plans to use 40 to 50 percent of this capacity for seasonal storage of Owens Valley water. The balance of basin capacity could be used for storing reclaimed water, State Project water, or both. The OLAC study has concluded that 20,000 AFY of reclaimed water produced by the city's Sepulveda Water Reclamation Plant could be used for basin replenishment and later recapture. It is likely that the reclaimed water would be percolated at the Tujunga spreading grounds located north of the treatment facility. This level of reuse would provide a dilution factor on the order of four to five with respect to the safe yield of the basin.

Anaheim Forebay

Much of metropolitan Orange County is underlain by the Santa Ana Groundwater Basin, as illustrated in Figure II-6. The basin is managed by the Orange County Water District (OCWD) which was formed in 1933 under authority of the State Legislature. The basin is not adjudicated; groundwater extractions fluctuate with the weather conditions and average about 240,000 AFY. The major area of groundwater recharge for the basin is the Anaheim Forebay.

Groundwater Replenishment. Replenishment of groundwater supplies in Orange County is accomplished by percolation of storm runoff, imported water, and base flows of the Santa Ana River. The Orange County Water District owns approximately 750 acres of the Santa Ana River bed which is used for groundwater replenishment and storm water channelization. The OCWD also operates two replenishment basins adjacent to the river channel (Warner Basin and Burris Basin) as well as one off-channel facility (Anaheim Lake). The total replenishment facilities are designed to percolate up to 300,000 AFY of water. Some incidental reuse has occurred as part of this program via discharge of wastewater from San Bernardino and Riverside Counties into the Santa Ana River. Estimates indicate that this discharge could represent as much as 50 percent of the base flow of the Santa Ana River (II-5).

The use of reclaimed water for groundwater replenishment in the Anaheim Forebay has been proposed to augment the existing supply of native and imported replenishment waters. The project under consideration would initially provide 12,000 AFY of reclaimed water from the proposed Anaheim Forebay Water Reclamation Plant (14,000 AFY design flow) for spreading at Anaheim Lake. An additional 12,000 AFY could be developed in the future when the plant is expanded. This level of reuse would represent approximately 8 percent of the total input to the basin.

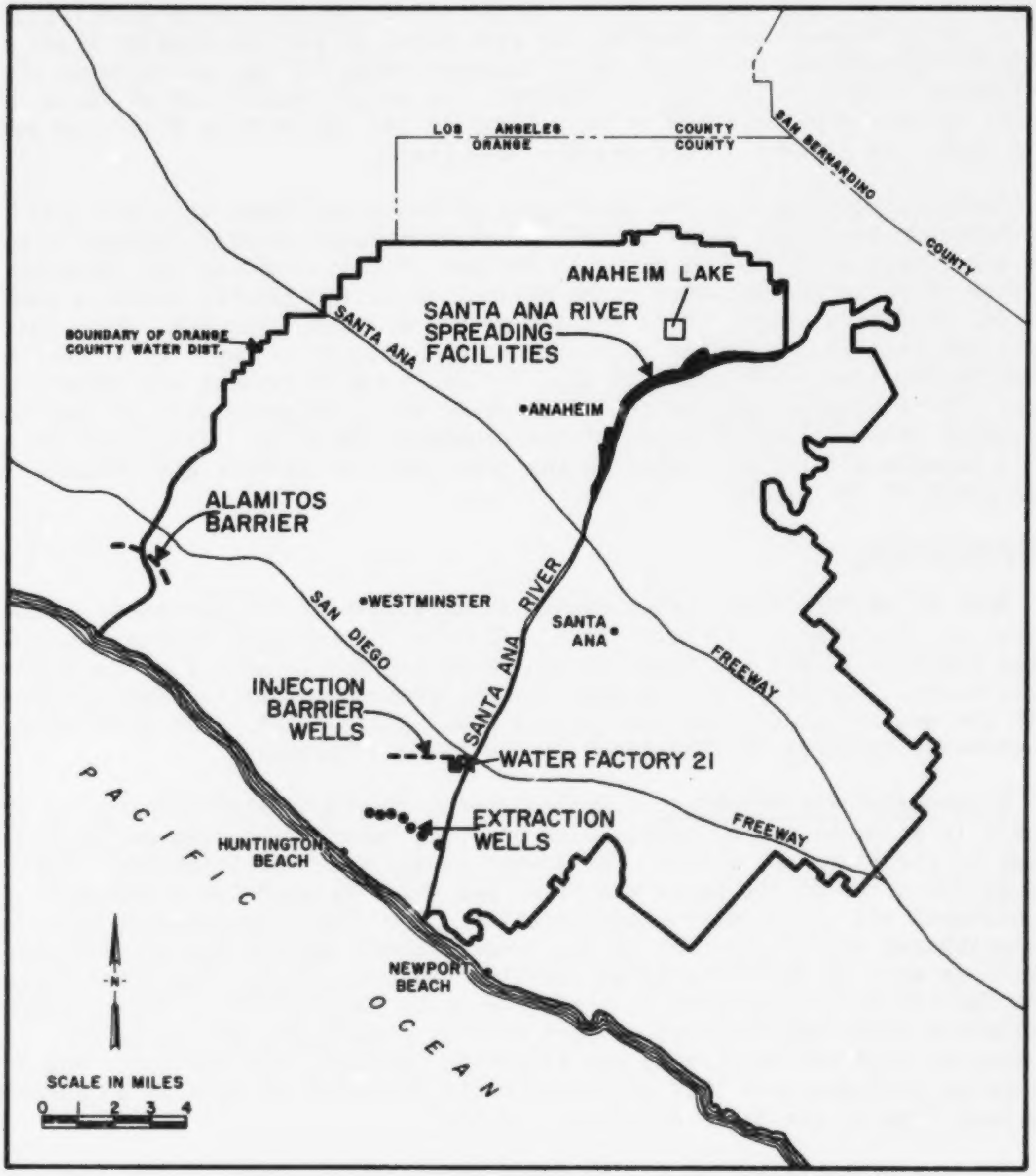

FIGURE II-6 ORANGE COUNTY GROUNDWATER RECHARGE FACILITIES AND SALT WATER INTRUSION BARRIERS

Talbert Gap

Another one of the Orange County Water District's management responsibilities is to protect the groundwater basin from salt water intrusion by establishing hydraulic intrusion barriers. OCWD has operated the Orange County Coastal Barrier project since 1976, which has prevented massive intrusion in an area stretching across a three-mile front between the cities of Huntington Beach and Newport Beach known as the Talbert Gap (see Figure II-6). The barrier consists of two separate well fields, one for extraction and one for injection. The extraction field is made up of seven wells located approximately two miles inland from the coast which intercept brackish water and return it to the ocean. The injection field consists of a series of 23 wells located further inland which deliver fresh water into the underground aquifers to form a water mound, blocking further passage of saline water. The barrier also provides the added benefit of local groundwater replenishment.

The injected water is a blend of native water and reclaimed water supplied by OCWD's Water Factory 21. This facility is designed to treat approximately 17,000 AFY of secondary effluent produced at the neighboring Orange County Sanitation Districts's treatment plant. Processes at Water Factory 21 include high-lime treatment, air stripping, recarbonation, multimedia filtration, activated carbon adsorption, reverse osmosis demineralization, and chlorine disinfection. On an average basis, about 11,000 AFY of reclaimed water is injected into the barrier system. Studies conducted at Water Factory 21 have indicated that the final effluent complies with drinking water standards and that concentrations of priority pollutants are generally low.

HEALTH EFFECTS STUDY GOALS AND OBJECTIVES

The primary goal of the Health Effects Study has been to develop a data base which would enable health and regulatory authorities to determine whether the use of reclaimed water for groundwater replenishment at the Whittier Narrows project should be maintained at the present level, cut back, or expanded. Two objectives were necessary to meet this goal; first to determine if the historical level of reuse had impacted either groundwater quality or human health, and second, to assess the relative impacts of the different replenishment sources on groundwater quality.

A second goal has been to provide definitive information to the Department of Health Services which could be used as a basis for developing statewide reclamation criteria for groundwater replenishment. These criteria would be based on such relevant aspects of a project as treatment provided, effluent quality and quantity, spreading operations, soil characteristics, hydrogeology, residence time, and distance to withdrawal.

Study Strategy

To assess the health effects of groundwater replenishment, a wide range of interdisciplinary research tasks have been performed for the four study sites, employing hydrogeological, chemical, toxicological, and epidemiological techniques.

- Water quality characterizations of groundwater, reclaimed water, and other replenishment sources in terms of their microbiological, inorganic chemical and organic chemical content.

- Toxicological and analytical studies of groundwater, reclaimed water and other replenishment sources designed to isolate and identify health significant constituents not likely to be found by standard water quality monitoring.

- Percolation studies to evaluate the efficacy of soil for attenuating chemical contaminants in reclaimed water.

- Hydrogeological studies to determine the movement of reclaimed water through the groundwater system and the relative contribution of reclaimed water to municipal water supplies.

- Epidemiology studies of populations ingesting reclaimed water to determine if their health characteristics differ significantly from a demographically similar control population.

The specific evaluation of each site differed in terms of emphasis, with the majority of work directed towards the Montebello Forebay and the Whittier Narrows groundwater replenishment project. This was the only one of the selected study sites which had utilized reclaimed water for groundwater replenishment for a sufficient period of time to allow for meaningful evaluation of water quality and human health effects. The specific design for the Montebello Forebay incorporated all of the elements listed above in a manner that allowed for some degree of independent evaluation of each research task, yet at the same time created an interdependence among the different study elements for definitive interpretation of final results.

The Montebello Forebay portion of the Health Effects Study consisted of hydrogeologic investigations designed to provide a basis for correlating water quality data to the degree that a given well had been impacted by replenishment activities and to derive population exposure estimates for an epidemiology study. Water quality characterizations were performed for selected Montebello Forebay wells, Los Angeles County Sanitation Districts' reclamation plants, imported water sources, and storm runoff. These same water sources were toxicologically evaluated by employing mutagenic screening techniques along with liquid chromatographic and quantitative/qualitative analytical procedures to isolate health-significant constituents. In addition, a pilot test basin study was conducted to assess the effects of vertical percolation on inorganic and organic chemicals found in reclaimed water.

Work conducted for the San Fernando Basin and Anaheim Forebay sites was designed to provide background information for planned replenishment projects and to assess, if possible, the effects of incidental reuse, while work done for the Talbert Gap area was conducted primarily to provide corroborative data for ongoing studies sponsored by the Orange County Water District. Specific tasks for the San Fernando Basin study site included chemical and biological monitoring of selected groundwater wells, reclaimed water, and dry weather runoff (which represented the worst case recharge for base flow of the Los Angeles

River). The different water sources were also evaluated for mutagenic characteristics. With the addition of virus monitoring, similar work was performed for the two Orange County sites. Water sources evaluated included domestic wells located in the Anaheim Forebay, observation wells located in the Talbert Gap, and Water Factory 21.

Although some study tasks were assigned to subcontractors, most of the work was performed by the Sanitation Districts, including the inorganic chemical analyses, the microbiological sampling, the toxicological assays, the pilot percolation study, the major portion of the trace organics analyses, and a portion of the hydrogeologic studies. Subcontracted work consisted of the epidemiology study which was performed by the University of California at Los Angeles (UCLA) School of Public Health, trace organics analyses performed by the Metropolitan Water District, water distribution characterizations performed by Bookman-Edmonston Engineering, Inc., and mammalian cell transformation testing performed by the University of Southern California Cancer Research Center. Assistance and direction during the course of the study were provided by two technical advisory committees and by the California Department of Health Services.

Expenditures for the three and one half year study amounted to almost $1.6 million. A total of $1,134,000 was provided by the Orange and Los Angeles Counties Water Reuse Study, of which 87.5 percent was funded by the Environmental Protection Agency and the California State Water Resources Control Board, and the remainder by six local water and wastewater agencies. Funds totaling almost $500,000 were provided by the EPA Health Effects Research Laboratory and the California Department of Water Resources for the epidemiology study.

Health Effects Study Final Report

The results of each element of the Health Effects Study are presented in the remaining chapters and appendices of this report. The overall summary, conclusions, and recommendations of the study have been presented separately in the first chapter. Three reports on the epidemiologic portion of the study (II-6, II-7, II-8) have been prepared under separate cover by the UCLA School of Public Health. Because of their size, they have not been appended to this document, but have been summarized in the last chapter, with portions of the text from the reports included where appropriate.

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CHAPTER III

WATER QUALITY CHARACTERIZATIONS

INTRODUCTION

One of the most important questions which arises in the reuse of wastewater is whether there is any significant health risk associated with the ingestion of reclaimed water because of its microbial or chemical content. For groundwater replenishment in particular, there is concern that such contaminants, if present in reclaimed water, may ultimately become part of a potable drinking water supply, creating the potential for disease transmission. One goal of the Health Effects Study was to evaluate the specific impacts of groundwater replenishment from an inorganic chemical, bacterial and viral standpoint.

This chapter presents the results of the different water quality evaluations conducted for the Health Effects Study. It has been divided into three sections as follows: the first describes the types of samples collected for each of the four study areas; the second section presents the results of analyses for the traditionally monitored inorganic, gross organic, and bacterial parameters; and, the third section presents the results of a separate testing program for virus and coliform bacteria using high-volume sampling techniques.

SAMPLING SITES

Water quality characterizations were conducted for each of the four Health Effects Study sites: the Montebello Forebay and the San Fernando Basin in Los Angeles County and the Anaheim Forebay and the Talbert Gap in Orange County. Information on the hydrogeologic features of each site has been presented in Chapter II. With regard to the work conducted at each site, major emphasis was placed on the Montebello Forebay and the water quality impacts of the Whittier Narrows groundwater replenishment project. Various replenishment sources (reclaimed water, imported water, and storm water) and Montebello Forebay well water were characterized. For the San Fernando Basin, characterizations were performed for reclaimed water, well water, and dry weather runoff, while for the two Orange County sites, characterizations were performed for reclaimed water and well water. Specific information on the types of samples collected is presented in the following text.

Montebello Forebay

To evaluate the Whittier Narrows groundwater replenishment project, samples were collected from each of the three replenishment sources: reclaimed water, imported water, and storm water. Reclaimed water was obtained from the Los Angeles County Sanitation Districts' San Jose Creek, Whittier Narrows, and Pomona Water Reclamation Plants (see Figure III-1).

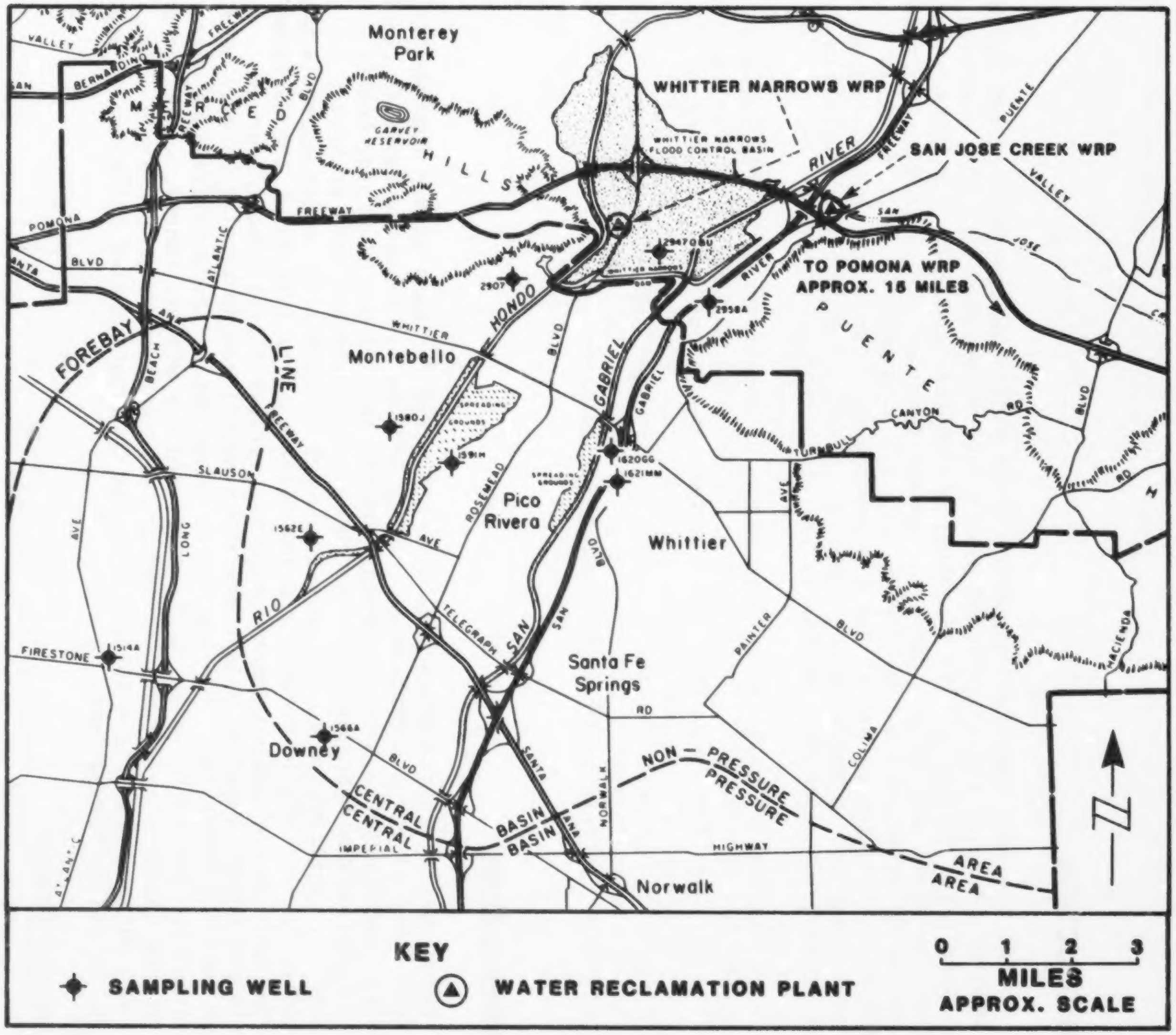

FIGURE III-1 SAMPLING POINTS FOR MONTEBELLO FOREBAY

Unit processes at the San Jose Creek and Whittier Narrows facilities consist of primary sedimentation, activated sludge aeration, final sedimentation, dual media filtration, chlorination and dechlorination. The design flows of these plants are 62.5 MGD (70,000 AFY) and 15 MGD (17,000 AFY), respectively. The Pomona Water Reclamation Plant (WRP), a 10 MGD (11,000 AFY) facility, employs the same unit processes described above except that activated carbon filtration is used in place of dual media filtration. All three facilities treat domestic waste with some industrial input (<15 percent). Toxic discharges, for the most part, have been controlled through the implementation of an Industrial Wastewater Ordinance/Permit Program which has established industrial wastewater effluent limits for heavy metals, chlorinated hydrocarbons, and cyanide.

The imported water delivered to the spreading grounds which consists of varying blends of Colorado River water and State Project water, receives no treatment prior to use, other than the addition of chlorine at various points in the distribution system to prevent fouling. Consequently, imported water samples (both Colorado River and State Project waters) were collected at a diversion point prior to entering the Metropolitan Water Districts' La Verne treatment plant. Storm water samples were collected at the forebay to the Rio Hondo spreading grounds after periods of sufficient precipitation.

Ten Montebello Forebay wells were chosen for study: one control well located above the influence of the spreading operation and nine wells within the Forebay proper (see Figure III-1). These ten wells were selected from a network of 16 Montebello Forebay wells which form the basis for an intensive monitoring program (III-1) operated under the joint sponsorship of the Central and West Basin Water Replenishment District, the Los Angeles County Flood Control District, and the Sanitation Districts. This program, implemented in 1972, was designed to monitor changes in water quality throughout the Forebay and to determine the impacts (if any) of the groundwater replenishment project. Wells selected for the monitoring program are located in the vicinity of the Whittier Narrows, adjacent to the spreading grounds, a short distance from the spreading grounds in the direction of groundwater flow, and at the downstream limit of the Forebay area. The key wells were also selected to provide data on the water quality characteristics of both the shallower aquifers in hydraulic continuity with the ground surface and the deeper aquifers which have continuity with the overlying aquifers. All but one of the 16 key wells are used for domestic supply.

The ten wells selected from this program for the Health Effects Study are listed in Table III-1. As previously mentioned, one of the ten wells (2947Q) was used as a control due to its location above the Whittier Narrows Dam and consequently, above the sphere of influence of the spreading operations. The remaining nine wells, to varying degrees were assumed to contain reclaimed water. The degree of impact for each well was further substantiated using a sulfate tracer model as discussed in Chapter VI. The results of the modeling work indicated that Well 2958A and 1514A (see Figure III-1) appeared to be only slightly impacted by the replenishment project, containing on the average <5 percent reclaimed water from 1978 onward. The other seven wells (2907, 1580J, 1591H, 1620GG, 1621MM, 1562E, 1566A) contained greater proportions of reclaimed water averaging 14 percent for the same time period. Because of the approximate nature of the model, it was felt that these proportions could only

TABLE III-1

DATA ON MONTEBELLO FOREBAY WELLS INCLUDED IN THE HEALTH EFFECTS STUDY SAMPLING PROGRAM

LACFCD a/ Well Number	State b/ Well Number	Well Owner	Depth (ft)	Depth of Perforations (ft)	Aquifers Perforated	Chlorination c/ Status	Reclaimed d/ Water Impact
2847Q	2S/11W-05G1	City of Whittier	665	528-652	Silverado, Sunnyside(?)	$UnCl_2$	C
2958A	2S/11W-08A2	Beverly Acres Estates	150	155-190	Gardena	Cl_2	L
2907	2S/12W-01P2	City of Montebello	470	135-288	Sunnyside	Cl_2	H
1580J	2S/12W-15J3	South Montebello Irrigation Dist.	500	132-300	Hollydale or Jefferson, Lynwood(?), Silverado	$UnCl_2$	H
1591H	2S/12W-23B4	City of Pico Rivera	600	281-572	Silverado, Sunnyside	$UnCl_2$	H
1620GG	2S/11W-18Q1	San Gabriel Valley Water Co.	530	305-462	Lynwood, Silverado	$UnCl_2$	H
1621MM	2S/11W-19M1	La Habra Heights Municipal Water Dist.	728	184-698	Jefferson(?), Lynwood, Silverado, Sunnyside	$UnCl_2$	H
1562E	2S/12W-28A4	Park Water Co.	590	422-556	Silverado	$UnCl_2$	H
1514A	2S/12W-31M2	City of South Gate	883	500-600	Lynwood	$UnCl_2$	L
1566A	3S/12W-03M1	City of Downey	609	345-572	Lynwood, Silverado	$UnCl_2$	H

a/ LACFCD = Los Angeles County Flood Control District well number.

b/ State well numbering system is based on the township, range and section subdivision of the Public Land Survey.

c/ $UnCl_2$ = unchlorinated; Cl_2 = chlorinated.

d/ C = control well; L = low reclaimed water well (≤5%); H = high reclaimed water well (>5%).

be used as gross estimates. Rather than relying on numerical estimates, subsequent references to the relative impacts of reclaimed water on the wells were expressed in less specific terms as follows: those wells containing ≤5 percent reclaimed water from 1978 onward were designated as low reclaimed water wells, while those wells containing >5 percent reclaimed water were designated as high reclaimed water wells.

All ten wells selected for study are used for domestic service and are owned by either private water companies, cities, or public utilities. Only two of the ten wells are routinely chlorinated at the well site (see Table III-1), prior to distribution.

San Fernando Basin

Water quality characterizations performed for the San Fernando Basin were designed to provide background information for the proposed Sepulveda Recharge Project. Samples were collected from the Los Angeles/Glendale Water Reclamation Plant (see Figure III-2), in lieu of the Sepulveda WRP, which at the time of sample collection, was under construction. The Los Angeles/Glendale WRP is a 20 MGD (22,000 AFY) tertiary treatment plant which provides such unit processes as primary sedimentation, conventional activated sludge aeration, final sedimentation, dual-media filtration and chlorination.

Samples were also collected from an unlined reach of the Los Angeles River at the Headworks Spreading Grounds which serves as a catchment for dry weather urban drainage. These samples were used to assess the potential groundwater quality impact of replenishment from the Los Angeles River. Groundwater samples were collected from two Department of Water and Power domestic well fields: the Pollock wells and the North Hollywood wells. As indicated in Figure III-2, the Pollock wells are located south of the Los Angeles River sampling point, near the lower boundary of the San Fernando Valley Basin watershed. The well field is made up of four wells connected by a common collector line. At the time the Health Effects Study samples were taken, only two of the four wells were in operation. Hydrogeologic data for these wells are listed in Table III-2. The North Hollywood wells (see Figure III-2) are located south of the Tujunga spreading grounds, the proposed replenishment site for the Sepulveda Project. This well field which contains 35 individual wells (also connected to a common collector line) is the largest in the San Fernando Basin. Wells are put into production based on demand; consequently not all of the wells operate simultaneously. At the time the first San Fernando Basin samples were collected, only one North Hollywood well was on-line (see Table III-2). For the sake of consistency, subsequent samplings of this well field were limited to the same well.

Anaheim Forebay

Water quality characterizations performed for the Anaheim Forebay were also designed to provide background data, in this case for the Anaheim Forebay Groundwater Replenishment Project. Reclaimed water to be supplied to the project would be provided by the Orange County Water District's (OCWD) proposed Anaheim Forebay WRP. Unit processes at the proposed facility would include primary sedimentation, conventional activated sludge aeration, final sedimentation, and advanced treatment similar to that provided by OCWD's Water Factory

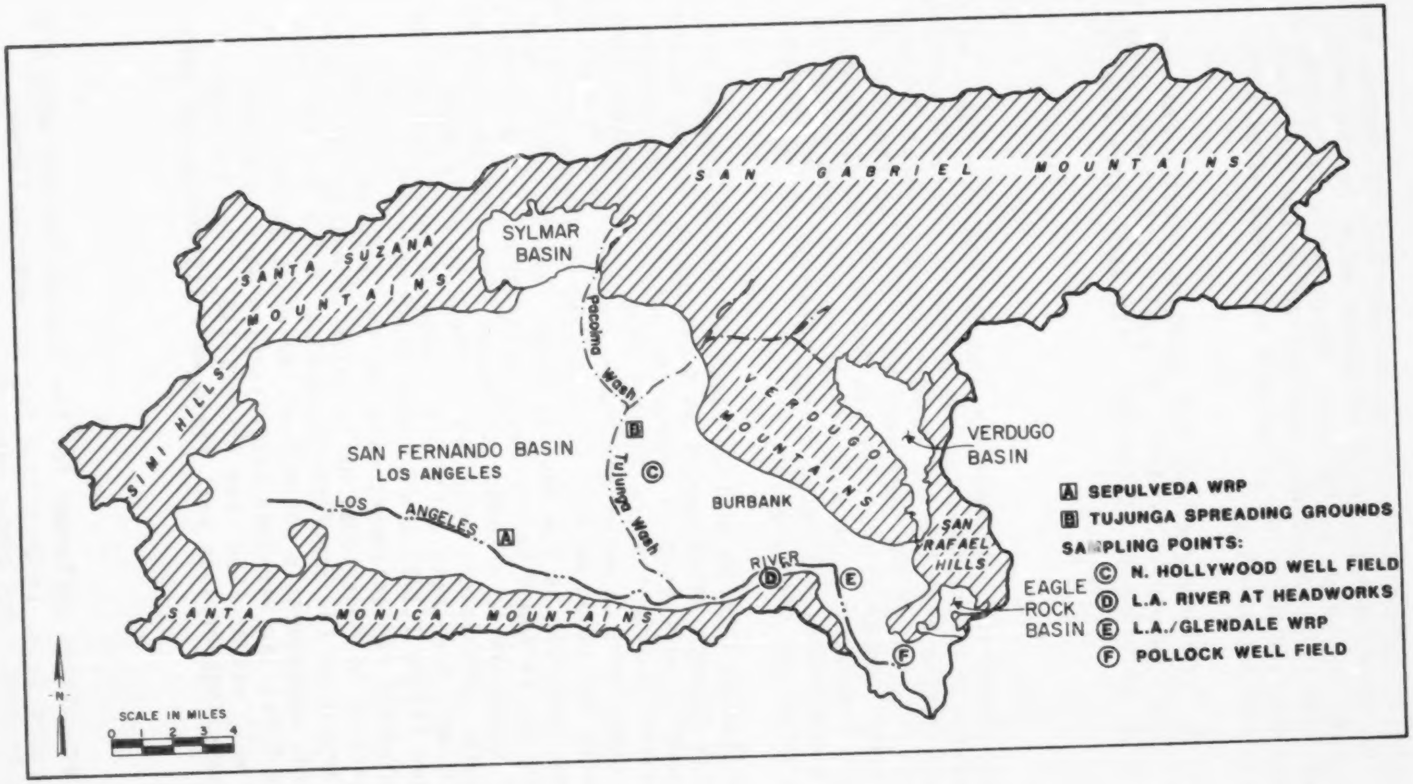

FIGURE III-2 SAMPLING POINTS FOR THE SAN FERNANDO BASIN

TABLE III-2

DEPARTMENT OF WATER AND POWER WELLS INCLUDED IN THE HEALTH EFFECTS STUDY SAMPLING PROGRAM

DWP[a] Well Number	LACFCD[b] Well Number	State[c] Well Number	Depth (ft)	Perforations (ft)
Pollock #4	3859E	1S/13W-4L2	245	59-234
Pollock #6	3958H	1S/13W-4L3	268	100-253
North Hollywood #5	3810S	1N/14W-6P1	414	110-391

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[a] DWP = City of Los Angeles, Department of Water and Power.

[b] LACFCD = Los Angeles County Flood Control District.

[c] State well numbering system is based on the township, range and section subdivision of the Public Land Survey.

21, a 15 MGD (17,000 AFY) facility located at the mid-point of the Orange County coastline (see Figure III-3). Unit processes at Water Factory 21 include high-lime treatment, air stripping, recarbonation, multi-media filtration, activated carbon adsorption, reverse osmosis demineralization, and chlorination (III-2). To simulate the quality of effluent to be produced by the Anaheim Forebay WRP, water quality characterizations were performed for Water Factory 21.

Four Anaheim Forebay wells were also selected for background evaluation (see Figure III-3). All of the wells are used for domestic production; two of the four were part of an ongoing basin-wide water quality monitoring program (III-3). Additional information on the Anaheim Forebay wells is presented in Table III-3.

Talbert Gap

Water quality characterizations performed for the fourth sampling site were conducted both to evaluate the effects of injecting reclaimed water into groundwater aquifers for prevention of saltwater intrusion and to provide corroborative data for ongoing studies sponsored by the Orange County Water District. In the case of the Talbert Barrier, the injection water was generally a blend of 40 percent activated carbon effluent and 20 percent reverse osmosis effluent provided from Water Factory 21 combined with 40 percent deep well water. Consequently, samples collected from Water Factory 21 for the Anaheim Forebay characterizations were also used to evaluate the Talbert Gap Study site. In addition, two observation wells located north of the injection barrier (see Figure III-3) were selected for evaluation. These wells were installed by OCWD to monitor the Talbert Barrier project (III-4). They were specially constructed to allow for differential sampling of the underlying groundwater aquifers. Specific information on the two observation wells is presented in Table III-4. With one exception, samples collected from these wells for the Health Effects Study were drawn in equal proportion from each of the aquifers tapped.

WATER QUALITY ANALYSES

The objective of this phase of study was to develop a water quality data base for assessing health risk in terms of traditionally monitored inorganic constituents, gross organics, and bacteria. The analytical methodology for these parameters has been well-developed (III-5) and is readily available. In addition, the specific health hazards have been well established (III-6). Consequently, by collecting data pertaining to the concentration and frequency of occurrence of these constituents in groundwaters and replenishment waters, it was possible to determine 1) whether there were constituents in groundwater at health significant concentrations that could be directly attributed to the use of reclaimed water or other sources of water for replenishment purposes, 2) whether the absence of contaminants in groundwater signified that additional removal had occurred during the replenishment process, and 3) whether any water quality trends had occurred in the groundwater over time as a result of artificial replenishment.

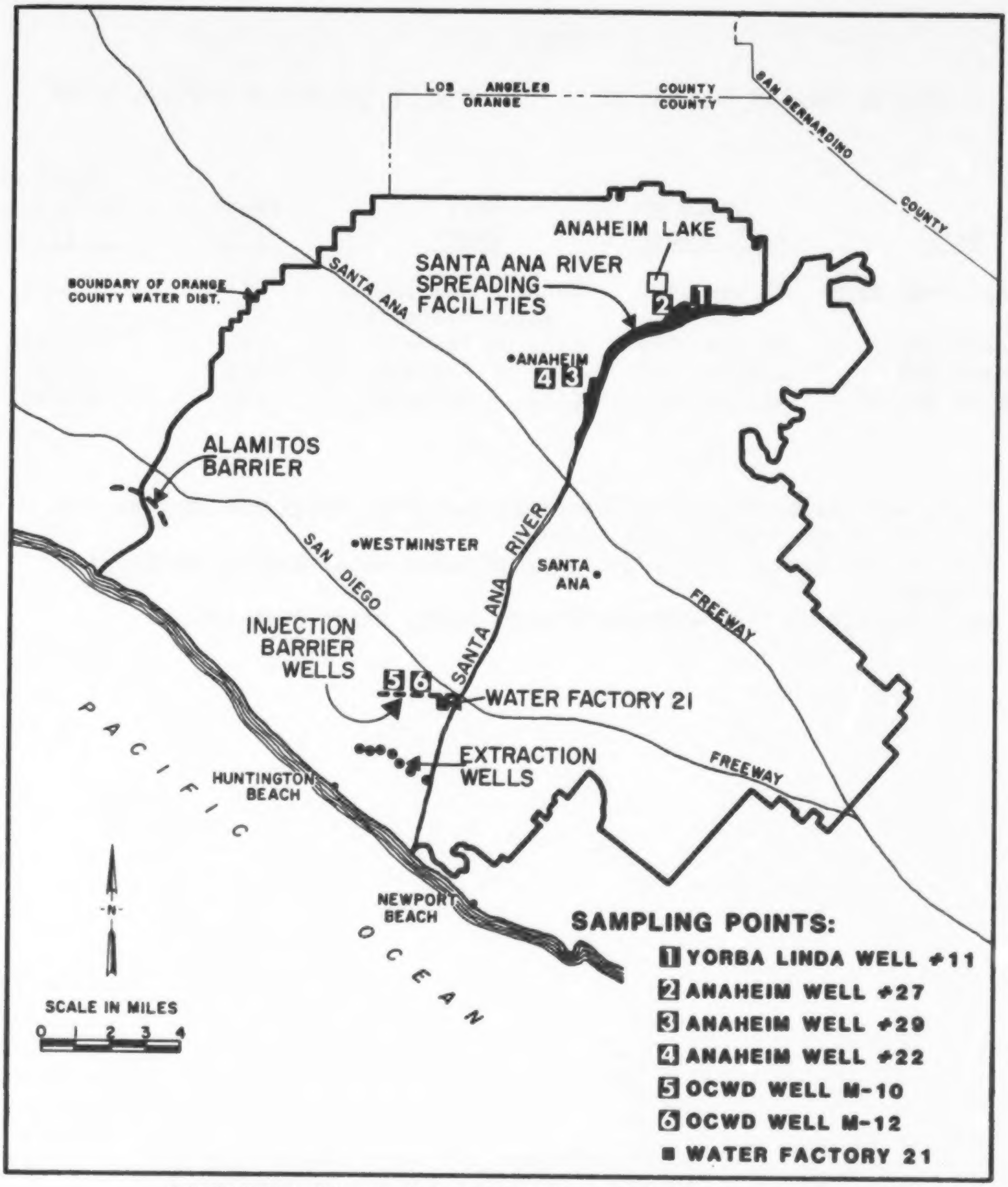

FIGURE III-3 SAMPLING POINTS FOR ORANGE COUNTY STUDY SITES: ANAHEIM FOREBAY AND TALBERT GAP

TABLE III-3

DATA ON ANAHEIM FOREBAY WELLS INCLUDED IN THE HEALTH EFFECTS STUDY

Well	State [a/] Well Number	Well Owner	Depth (ft)	Depth of Perforations (ft)
Yorba Linda #11[b/]	4S/09W-04G1	Yorba Linda County Water District	547	115-511
Anaheim #27	3S/09W-32P3	City of Anaheim	295	240-282
Anaheim #29	4S/10W-11Q2	City of Anaheim	408	[c/]
Anaheim #22 [b/]	4S/10W-14D2	City of Anaheim	446	368-421

[a/] State well numbering system based on township, range and section subdivision of the Public Land Survey.

[b/] Part of the Orange County Groundwater Basin Water Quality Monitoring Program.

[c/] Well log not on file with the Orange County Water District.

TABLE III-4

DATA ON TALBERT BARRIER OBSERVATION WELLS INCLUDED IN THE HEALTH EFFECTS STUDY

Casing Number [a]	Aquifer Perforated	Depth (ft) Well M-10	Depth (ft) Well M-12	Depth of Perforations (ft) Well M-10	Depth of Perforations (ft) Well M-12
1	Talbert	165	115	80-160	70-110
2	Alpha	200	225	175-195	130-220
3	Beta	245	265	215-240	240-260
4	Lamda	310	355	280-305	330-350

[a] Each observation well contained four casings in a 20 in. diameter hole; casings at 0 to 40 ft. were 4 in. Schedule 80 PVC; casings at depths below 40 ft. were 2 in. Schedule 80 PVC.

Methods

The inorganic parameters selected for evaluation included traditionally monitored minerals, nutrients, and trace metals many of which are regulated under the Interim Primary and Secondary Drinking Water Standards (III-7). Physical parameters monitored in study samples included pH, color, and turbidity. Bacterial indicators measured included both total and fecal coliforms, fecal streptococci, and total plate count. A complete listing of water quality parameters evaluated has been presented in Table III-5.

Specific sampling sites within each of the four study areas can be broken down as follows:

Montebello Forebay

- 8 Wells - unchlorinated samples
- 2 Wells - chlorinated samples
- 3 WRPs - unchlorinated secondary effluent samples
  - chlorinated secondary effluent samples*
  - chlorinated/dechlorinated tertiary effluent samples
- 2 Imported Sources - Colorado River water samples
  - State Project water samples
- Storm water samples

San Fernando Basin

- 1 Well - unchlorinated samples
- 2 Wells - unchlorinated composite samples
- 1 WRP - chlorinated tertiary effluent samples
- Los Angeles River - dry weather runoff samples

Anaheim Forebay

- 1 Well - chlorinated samples
- 3 Wells - unchlorinated samples
- 1 WRP - chlorinated activated carbon effluent samples**
  - unchlorinated and chlorinated reverse osmosis effluent samples**

Talbert Gap

- 2 Wells - unchlorinated samples
- 1 WRP - chlorinated activated carbon effluent samples**
  - unchlorinated and chlorinated reverse osmosis effluent samples**

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* These samples were batch chlorinated in the laboratory using chlorine doses and contact times equivalent to the chlorination practices followed at the Sanitation Districts' WRPs.

** These samples have undergone high-lime treatment, air stripping, recarbonation, and mixed-media filtration prior to either activated carbon adsorption or reverse osmosis demineralization.

TABLE III-5

LIST OF CONSTITUENTS FOR WATER QUALITY CHARACTERIZATIONS

Parameter	Significance	Method
Turbidity	PDWS [a]	HACH Turbidimeter
Color	SDWS [b]	Nessler
pH	Aesthetic	pH Meter
Dissolved Solids	SDWS	Filtration/Evaporation
Total Alkalinity	Aesthetic	Titration
Chloride	SDWS	Mercuric Nitrate
Sulfate	SDWS	Turbidimeter
Nitrate - Nitrogen	PDWS	Cadmium Reduction
Nitrite - Nitrogen	Health	Colorimetric
Ammonia - Nitrogen	Health	Distillation/Titration
Phosphate	Agricultural	Ascorbic Acid
Fluoride	PDWS	Specific Ion Electrode
Cyanide	Health	Distillation
Total Hardness	Health	Titration
Arsenic	PDWS	Atomic Absorption
Barium	PDWS	Atomic Emission
Cadmium	PDWS	Atomic Absorption
Chromium	PDWS	Atomic Absorption
Copper	SDWS	Atomic Absorption
Iron	SDWS	Atomic Absorption
Lead	PDWS	Atomic Absorption
Manganese	SDWS	Atomic Absorption
Mercury	PDWS	Atomic Absorption
Nickel	Health	Atomic Absorption
Selenium	PDWS	Atomic Absorption
Silver	PDWS	Atomic Absorption
Sodium	Health	Atomic Emission
Zinc	SDWS	Atomic Absorption
Total Organic Carbon	Health	TOC Analyzer
Bromide	Health	Colorimetric
Coliforms (total & fecal)	PDWS	Multiple Tube Fermentation
Fecal Streptococci	Health	Multiple Tube Fermentation
Total Plate Count	Health	Plating

[a] PDWS = primary drinking water standard.
[b] SDWS = secondary drinking water standard.

At least three grab samples were collected from each specific well site at different times over the course of the two-year sampling period (February 1979 to February 1981). The Montebello Forebay, Anaheim Forebay, and North Hollywood wells, in service at the time samples were collected, required no special on-site sampling procedures. However, this was not the case for the Pollock wells and Talbert Barrier observation wells which were not in service at the time of sample collection. Consequently, in order to obtain representative samples, special sampling procedures were followed. For the Pollock wells, Department of Water and Power staff were contacted several days prior to the sample collection date to arrange for the wells to be turned on the night before sampling. For the OCWD observation wells, each of the aquifer access lines was evacuated prior to sample collection and allowed to refill before a sample was collected. Because of the large body of data available for the water reclamation plants, some of the WRP sites were only sampled twice. Each of the imported water sources was sampled three times as was the dry weather runoff collection site in the Los Angeles River. The considerable rainfall that occurred during the two-year sampling period allowed for six storm water samples to be taken at the Rio Hondo Forebay. In all, 90 samples were collected.

The bacterial assays and inorganic chemical analyses were performed according to Standard Methods (III-5). Specific procedures used for each parameter are listed in Table III-5. Total organic carbon analyses were performed using the ampul method on an Oceanography International, Corp. instrument according to manufacturer's instructions.

Results

The results from the chemical and bacterial analyses for each of the 90 Health Effects Study samples, along with primary and secondary standards for 19 of the 34 parameters evaluated, have been included in Appendix A of this report. Summarized data are shown in Tables III-6 through III-8.

Montebello Forebay. Examination of the data collected for the Montebello Forebay study area shows that all of the groundwaters and two of the replenishment (reclaimed and imported) met primary drinking water standards. Storm water, however, contained concentrations of lead in excess of the specified maximum contaminant level (MCL) as indicated in the data summary presented in Table III-6.

More frequent violations of secondary standards were observed in the different source waters tested (see Table III-6). Tertiary and secondary effluent samples generally exceeded the secondary MCL for color; State Project water samples exceeded the MCL for color; storm water samples exceeded the MCLs for turbidity, color, iron, and manganese. On the average, none of the Forebay wells exceeded the secondary limits. However, on an individual basis (see Appendix A) three of the ten wells tested did have samples with concentrations in excess of secondary MCLs including Well 1562E for turbidity, color, iron, and manganese; Well 1621MM for iron; and Well 1514A for manganese.

Coliform and fecal streptococci concentrations in both chlorinated and unchlorinated well waters were less than 2 MPN/100 mL. Averaged total plate counts (TPC) for the unchlorinated wells ranged from <1/mL to <17/mL and for the

TABLE III-6

AVERAGED WATER QUALITY DATA FOR MONTEBELLO FOREBAY SAMPLES

Parameter	Drinking Water Standards[a]		Reclaimed Water[b]			Imported Water			Unchlorinated Well Water			Chlorinated Well Water	
	Primary	Secondary	$Cl_2/DeCl_2$ 3°	Cl_2 2°	$UnCl_2$ 2°	Storm Water	Colorado River	State Project	High[c]	Low[d]	Control[e]	High[c]	Low[d]
Turbidity, NTU	0.5-5	5	0.8	2.3	1.9	72.2	1.9	2.4	1.7	< 0.2	< 0.5	0.5	0.3
Color, CU	-	15	22.5	28.3	36.7	698.3	< 5	21.7	< 7	< 5	< 5	< 5	< 5
pH	-	-	7.23	7.73	7.52	7.68	8.00	8.07	7.65	7.81	7.90	7.51	7.36
Dissolved Solids, mg/L	-	500-1500	568	588	560	179	664	339	464	478	277	492	713
Total Alkalinity, mg/L $CaCO_3$	-	-	220	276	276	59	127	72	162	201	161	189	258
Chloride, mg/L Cl	-	250-600	133	129	111	19	96	61	62	45	18	105	67
Sulfate, mg/L SO_4	-	250-600	113	102	102	46	308	34	125	123	48	179	200
Nitrate, mg/L N	10.0	-	0.34	0.13	0.19	1.78	0.16	0.60	2.31	1.51	0.93	0.57	3.68
Nitrite, mg/L N	-	-	0.40	0.52	0.50	0.14	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Ammonia, mg/L N	-	-	13.7	20.7	20.5	1.3	< 0.1	< 0.1	< 0.1	< 0.2	< 0.2	< 0.1	< 0.1
Phosphate, mg/L PO_4	-	-	10.6	6.9	7.2	2.4	0.8	0.3	0.6	0.2	< 0.1	< 0.1	0.7
Fluoride, mg/L F	1.4-2.4	-	0.65	0.66	0.60	0.23	0.37	< 0.13	0.43	0.40	0.36	0.51	0.23
Cyanide, mg/L CN	-	-	< 0.01	< 0.01	0.02	0.02	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.02
Total Hardness, mg/L $CaCO_3$	-	-	194	212	211	100	334	93	242	309	255	279	445
Arsenic, mg/L As	0.05	-	0.003	0.004	0.003	0.010	0.003	0.002	0.004	0.003	0.002	0.004	0.002
Barium, mg/L Ba	1.0	-	0.22	0.20	0.23	0.26	0.46	0.16	0.29	0.29	0.29	0.33	0.54
Cadmium, mg/L Cd	0.01	-	< 0.002	0.004	0.004	0.002	0.002	< 0.001	<0.002	0.002	< 0.001	0.002	0.003
Chromium, mg/L Cr	0.05	-	< 0.01	< 0.01	< 0.01	0.02	< 0.01	< 0.01	<0.01	< 0.01	< 0.01	< 0.01	< 0.01
Copper, mg/L Cu	-	1.0	0.008	0.016	0.015	0.046	< 0.006	< 0.010	<0.007	< 0.005	< 0.005	< 0.006	0.014
Iron, mg/L Fe	-	0.3	< 0.06	0.07	0.09	9.13	0.18	0.22	0.40	0.02	< 0.01	0.07	< 0.02
Lead, mg/L Pb	0.05	-	< 0.02	0.02	0.03	0.09	< 0.01	< 0.02	<0.02	< 0.02	< 0.02	< 0.02	< 0.02
Manganese, mg/L Mn	-	0.05	< 0.01	0.02	0.02	0.18	0.01	0.01	<0.05	< 0.05	< 0.01	0.02	< 0.01
Mercury, mg/L Hg	0.002	-	< 0.0001	< 0.0001	0.0001	< 0.0001	< 0.0001	< 0.0001	<0.0001	< 0.0001	< 0.0001	0.0004	< 0.0001
Nickel, mg/L Ni	-	-	0.05	0.07	0.07	0.02	< 0.01	0.01	<0.01	< 0.09	< 0.01	0.01	0.02
Selenium, mg/L Se	0.01	-	< 0.003	0.003	0.003	< 0.003	< 0.003	< 0.002	<0.002	0.002	< 0.001	0.003	0.004
Silver, mg/L Ag	0.05	-	0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	<0.001	< 0.001	< 0.002	0.002	0.002
Sodium, mg/L Na	-	-	105	126	116	19	91	45	59	40	19	109	56
Zinc, mg/L Zn	-	5.0	0.03	0.05	0.05	0.10	< 0.01	0.05	0.02	< 0.01	0.09	0.14	0.03
TOC, mg/L C	-	-	11.2	14.1	12.6	16.4	3.2	4.3	0.8	0.6	0.3	2.2	0.7
Bromide, mg/L Br	-	-	< 0.30	0.32	0.31	0.14	0.11	0.22	0.21	0.18	0.05	0.38	0.18
Total Coliform, MPN/100 mL	-	-	8	< 8	$>5.0 \times 10^5$	$>6.2 \times 10^4$	< 2	14	< 2	< 2	< 2	< 2	< 2
Fecal Coliform, MPN/100 mL	-	-	< 2	< 2	$>2.8 \times 10^4$	$>8.7 \times 10^3$	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Fecal Strep, MPN/100 mL	-	-	< 2	< 2	$>8.8 \times 10^2$	$>1.1 \times 10^5$	< 2	< 3	< 2	< 2	< 2	< 2	< 2
Total Plate Count/mL	-	-	194	83	$>2.9 \times 10^4$	7.7×10^4	< 1	49	<17	< 1	4	< 1	<10

a/ California Domestic Water Quality and Monitoring Regulations, Articles 4 and 8, Title 22, California Administrative Code, 1977.
b/ $Cl_2/De\ Cl_2$ 3° = chlorinated/dechlorinated tertiary effluent; Cl_2 2° = batch chlorinated secondary effluent; $UnCl_2$ 2° = unchlorinated secondary effluent.
c/ Wells containing > 5 percent reclaimed water.
d/ Wells containing ≤ 5 percent reclaimed water.
e/ Wells containing no reclaimed water.

TABLE III-7

AVERAGED WATER QUALITY DATA FOR SAN FERNANDO BASIN SAMPLES

Parameter	Drinking Water Primary	Standards a/ Secondary	LA/Glendale b/ WRP Cl_2 3°	Dry Weather Run-off	Pollock c/ Wells $UnCl_2$	North c/ Hollywood Wells $UnCl_2$
Turbidity, NTU	0.5-5	5	0.9	3.0	<0.1	<0.1
Color, CU	-	15	23	53	<5	<5
pH	-	-	7.11	8.18	7.53	7.77
Dissolved Solids, mg/L	-	500-1500	545	802	669	283
Total Alkalinity, mg/L $CaCO_3$	-	-	153	235	223	215
Chloride, mg/L Cl	-	250-600	109	73	81	15
Sulfate, mg/L SO_4	-	250-600	149	282	199	37
Nitrate, mg/L N	10.0	-	2.57	2.07	2.55	4.16
Nitrite, mg/L N	-	-	0.29	0.08	<0.01	<0.01
Ammonia, mg/L N	-	-	8.3	<0.1	<0.1	<0.1
Phosphate, mg/L PO_4	-	-	12.8	0.5	0.3	0.2
Fluoride, mg/L F	1.4-2.4	-	0.85	0.55	0.37	0.37
Cyanide, mg/L CN	-	-	0.09	0.01	<0.02	0.01
Total Hardness, mg/L $CaCO_3$	-	-	172	460	373	239
Arsenic, mg/L As	0.05	-	0.007	0.006	0.003	<0.001
Barium, mg/L Ba	1.0	-	0.10	0.22	0.21	0.40
Cadmium, mg/L Cd	0.01	-	0.042	<0.001	<0.002	<0.001
Chromium, mg/L Cr	0.05	-	0.054	0.005	<0.002	0.002
Copper, mg/L Cu	-	1.0	0.048	0.011	0.017	<0.005
Iron, mg/L Fe	-	0.3	0.08	0.16	0.04	<0.01
Lead, mg/L Pb	0.05	-	<0.01	0.02	<0.01	<0.01
Manganese, mg/L Mn	-	0.05	0.018	0.035	<0.005	<0.005
Mercury, mg/L Hg	0.002	-	<0.0001	<0.0001	<0.0001	<0.0001
Nickel, mg/L Ni	-	-	0.25	0.02	<0.01	<0.01
Selenium, mg/L Se	0.01	-	0.005	0.005	0.005	0.003
Silver, mg/L Ag	0.05	-	<0.001	0.002	<0.002	<0.001
Sodium, mg/L Na	-	-	119	84	78	22
Zinc, mg/L Zn	-	5.0	0.12	0.02	<0.01	<0.01
TOC, mg/L C	-	-	10.4	6.9	0.9	0.4
Bromide, mg/L Br	-	-	0.65	0.36	0.40	0.26
Total Coliform, MPN/100 mL	-	-	<7	4.5×10^4	<2	<2
Fecal Coliform, MPN/100 mL	-	-	<2	3.4×10^3	<2	<2
Fecal Strep, MPN/100 mL	-	-	<2	1.0×10^3	<2	<2
Total Plate Count/mL	-	-	71	3.4×10^4	<3	2

a/ California Domestic Water Quality and Monitoring Regulations, Articles 4 & 8, Title 22, California Administrative Code, 1977.
b/ Cl_2 3° = chlorinated tertiary effluent.
c/ $UnCl_2$ = unchlorinated well water.

TABLE III-8

AVERAGED WATER QUALITY DATA FOR ORANGE COUNTY SAMPLES

Parameter	Drinking Water Standards a/		Anaheim Forebay Wells b/		Water Factory 21 c/		Talbert Barrier
	Primary	Secondary	Cl_2	$UnCl_2$	Activated Carbon Cl_2	Reverse Osmosis $UnCl_2/Cl_2$	Observation Wells $UnCl_2$
Turbidity, NTU	0.5-5	5	0.6	< 0.1	0.2	< 0.1	1.7
Color, CU	-	15	< 5	< 5	< 5	< 5	< 5
pH	-	-	7.69	7.77	7.02	7.16	7.92
Dissolved Solids, mg/L	-	500-1500	627	592	956	76	396
Total Alkalinity, mg/L $CaCO_3$	-	-	220	203	51	17	171
Chloride, mg/L Cl	-	250-600	104	87	296	30	69
Sulfate, mg/L SO_4	-	250-600	133	173	238	5	68
Nitrate, mg/L N	10.0	-	3.46	3.51	5.26 d/	0.43	1.65
Nitrite, mg/L N	-	-	< 0.01	< 0.01	< 0.01	0.17	0.01
Ammonia, mg/L N	-	-	< 0.1	< 0.1	8.3	2.4	< 0.1
Phosphate, mg/L PO_4	-	-	0.55	0.25	0.28	0.02	0.15
Fluoride, mg/L F	1.4-2.4	-	0.54	0.48	0.70	0.16	0.46
Cyanide, mg/L CN	-	-	< 0.01	< 0.02	< 0.01	0.01	< 0.01
Total Hardness, mg/L $CaCO_3$	-	-	323	331	256	2	176
Arsenic, mg/L As	0.05	-	0.004	< 0.003	0.002	< 0.001	0.003
Barium, mg/L Ba	1.0	-	0.21	0.38	0.16	< 0.01	0.25
Cadmium, mg/L Cd	0.01	-	< 0.002	< 0.003	< 0.006	< 0.001	0.002
Chromium, mg/L Cr	0.05	-	< 0.002	< 0.003	0.010	< 0.006	< 0.002
Copper, mg/L Cu	-	1.0	0.021	< 0.007	0.048	< 0.005	< 0.006
Iron, mg/L Fe	-	0.3	0.04	< 0.03	0.02	< 0.02	0.27
Lead, mg/L Pb	0.05	-	< 0.03	< 0.03	0.02	< 0.01	< 0.02
Manganese, mg/L Mn	-	0.05	< 0.006	< 0.005	< 0.005	< 0.005	0.017
Mercury, mg/L Hg	0.002	-	< 0.0001	< 0.0001	< 0.0004	< 0.0004	< 0.0001
Nickel, mg/L Ni	-	-	< 0.01	< 0.01	0.03	< 0.01	< 0.01
Selenium, mg/L Se	0.01	-	0.004	< 0.004	0.004	< 0.004	< 0.004
Silver, mg/L Ag	0.05	-	< 0.001	< 0.002	0.002	< 0.001	< 0.002
Sodium, mg/L Na	-	-	91	86	198	20	62
Zinc, mg/L Zn	-	5.0	0.02	< 0.01	0.04	< 0.01	0.02
TOC, mg/L C	-	-	1.74	0.87	6.64	0.50	0.96
Bromide, mg/L Br	-	-	0.19	0.28	0.96	0.12	0.13
Total Coliform, MPN/100 mL	-	-	<2	< 2	< 2	8	< 2
Fecal Coliform, MPN/100 mL	-	-	<2	< 2	< 2	< 3	< 2
Fecal Strep, MPN/100 mL	-	-	<2	< 2	< 2	< 2	< 2
Total Plate Count/mL	-	-	<1	< 3	< 1	50	4.3×10^3

a/ California Domestic Water Quality and Monitoring Regulations, Articles 4 and 8, Title 22, California Administrative Code, 1977.
b/ Cl_2 = chlorinated and $UnCl_2$ = unchlorinated wells.
c/ Cl_2 = chlorinated effluent; $UnCl_2$ = unchlorinated effluent.
d/ High results reflect nitrified influent to Water Factory 21.

chlorinated wells from <1/mL to <10/mL. Individual samples with concentrations at the upper end of the reported TPC ranges (205/mL for an unchlorinated well sample and 27.5/mL for a chlorinated sample) had corresponding coliform and turbidity concentrations at or below analytical detection limits.

Similar results were observed for the imported water samples, with slightly higher coliform and fecal streptococci concentrations reported for the State Project water samples. Total plate count concentrations for the State Project water samples were notably higher than those for the Colorado River water samples resulting in a higher average concentration. In this case, the sample with the highest total plate count (State Project water = 74/mL) also had the highest turbidity and coliform concentrations of the imported water samples.

Fecal coliform and fecal streptococci concentrations for the disinfected tertiary and secondary effluent samples were $\leq$2 MPN/100 mL; on the average total coliform concentrations were $\leq$8 MPN/100 mL, while total plate counts ranged from 83/mL for chlorinated secondary effluent to 194/mL for dechlorinated filtered effluent. Bacterial concentrations for undisinfected effluent and storm water samples were generally two to four orders of magnitude greater than those reported for disinfected effluent samples.

San Fernando Basin. Water quality data for the San Fernando Basin are presented in Table III-7. Data collected from the Los Angeles/Glendale WRP indicated that the samples tested complied with all primary and secondary standards with the exception of the primary MCLs for cadmium and chromium, and the secondary MCL for color. Dry weather runoff collected from the Los Angeles River complied with all of the primary MCLs and all but one of the secondary MCLs (color). All of the groundwater samples collected met both sets of standards.

When specifically comparing the groundwater samples, the Pollock well field appeared to be more mineralized than the North Hollywood well field in terms of such constituents as dissolved solids, chloride, sulfate, total hardness, and sodium. This occurred despite the fact that one of the Pollock well field samples had lower than expected concentrations (at least two times lower) for these constituents (see Appendix A). On the other hand, the nitrate concentrations in the Hollywood well were slightly higher than those found in the Pollock wells.

Coliform and fecal streptococci concentrations for the wells were $\leq$2 MPN/100 mL while average total plate count concentrations were <3/mL. Similar results were obtained for the disinfected effluent samples in terms of fecal bacteria. Total coliform and total plate count concentrations for the Los Angeles/Glendale effluent averaged <7 MPN/100 mL and 71/mL, respectively. As might be expected, bacterial concentrations recorded for the dry weather runoff samples were two to three orders of magnitude higher than concentrations recorded for the effluent samples.

Anaheim Forebay and Talbert Gap. Examination of the data collected for the Orange County sites, which are summarized in Table III-8, demonstrated that on the average, all of the groundwater and reclaimed water samples complied with primary and secondary drinking water standards. On an individual basis, one of the activated carbon effluent samples slightly exceeded the primary MCL for nitrate at a time when the influent to Water Factory 21 was a nitrified secondary effluent; one of the observation wells (M-12) had a lead concentration in excess of the specified primary MCL while the other observation well (M-10) had iron concentrations in excess of the secondary MCL (see Appendix A).

Coliform and fecal streptococci concentrations were <2 MPN/100 mL for the Anaheim Forebay wells, Talbert Barrier observation wells, and chlorinated activated carbon effluents. Coliform concentrations were slightly higher for the unchlorinated reverse osmosis samples with total and fecal coliform concentrations of 8 MPN/100 mL and 3 MPN/100 mL, respectively. Average total plate count concentrations ranged from <1/mL for the chlorinated Anaheim Forebay well samples to <3/mL for the unchlorinated well samples. Effluent TPC concentrations ranged from <1/mL for the chlorinated activated carbon effluent samples to 50/mL for the averaged chlorinated and unchlorinated reverse osmosis effluent samples. The observation wells had the highest average TPC concentration (4,300/mL).

Discussion of Water Quality Data

Because the sampling frequency for specific sites was somewhat limited, the data collected were compared to corresponding data available from other sources (including monitoring reports and research reports) to determine whether the study data were in general agreement with other water quality data.

Montebello Forebay. For the Montebello Forebay, corroborative data were obtained from the Central and West Basin Water Replenishment District's Annual Reports on Results of Water Quality Monitoring (III-8) and from National Pollutant Discharge Elimination System (NPDES) Reports prepared by the Sanitation Districts for the Los Angeles Regional Water Quality Control Board (III-9, III-10, III-11). Examination of imported water, storm water, and well water data which were obtained from the annual monitoring reports and of reclaimed water data which were obtained from the annual NPDES Reports, indicated that the historical data and Health Effects Study data were generally comparable. One exception was the total coliform data for tertiary effluents; the average total coliform concentration for the Health Effects Study samples was 8 MPN/100 mL compared to an average concentration of <2.2 MPN/100 mL reported on an annual basis.

Specific attention was focused on samples containing constituents at concentrations above drinking water standards. In the case of storm water, the monitoring data demonstrated that concentrations of lead, iron and manganese have historically exceeded MCLs and that on occasion, concentrations of other trace constituents such as barium, cadmium, and selenium have also exceeded MCLs. State Project water, on occasion, has contained iron at concentrations above the recommended limit while iron and/or manganese concentrations above standards have historically been reported in at least half of the intensively monitored wells, including the three Health Effects Study wells previously discussed, and the control well.

This situation has been of particular interest to the Replenishment District who commissioned a study in 1977 (III-12) to determine why high iron and manganese periodically occurred in surface flows and groundwater samples. The study concluded that the concentrations in the replenishment sources were typical of concentrations found in other western surface waters. Due to the variability of concentrations found in the groundwater and the changes in water chemistry as the water passes through the soil column, it appeared that the iron and manganese in the replenishment waters were not a determinant of the iron and manganese in groundwater.

This conclusion was substantiated by the data collected for the Health Effects Study. Again, the condition was not widespread. Excess iron and manganese concentrations were only reported in three wells, two of which were designated as "significantly impacted" wells while the third was designated as a "less significantly impacted" well according to the sulfate model. Because of the nature of the model used to derive these designations (i.e., high or low impact), the degree of impact for reclaimed water was also an indication of the degree of impact from the other replenishment sources (storm water and imported water). Since both high and low impacted wells contained excess concentrations of iron and manganese, it again appeared that the replenishment waters were not responsible for the iron and manganese groundwater condition.

Trends in groundwater quality were also examined using both the historical data and the Health Effects Study data. A noticeable temporal trend in mineral quality was observed. Concentrations of dissolved solids, alkalinity, sulfate, and total hardness in the highly impacted wells began to decline over time while concentrations in the less impacted wells began to increase. The phenomenon was explained by the shift from spreading highly mineralized Colorado River water to spreading blends of Colorado River water and the substantially less mineralized State Project water in the 1970s. The higher concentrations in the "low" wells reflected the subsequent time lag that occurred before the impact of the State Project water was fully seen in the groundwater system.

In terms of evaluating the relative impacts of the replenishment sources, comparisons of the high and low impacted wells and control well showed no significant differences that could be attributed to reclaimed water. For those constituents of health concern, concentrations were usually at such low levels that they could not be used to gauge impacts. The one exception was nitrate which was observed in wells at concentrations ranging from 1 to 4 mg/L. From a water reuse viewpoint nitrate is a constituent of particular significance because of the relatively high concentration of combined nitrogen commonly present in wastewater (in this case concentrations ranging from 14 to 21 mg/L) and the tendency for all nitrogenous materials to be converted to nitrate. Historically, reclaimed water has not been the only source of nitrogen to the groundwater system as considerable crop fertilization has been practiced within the Forebay. In any event, concentrations of nitrate in groundwater have not been of concern because levels have remained safely below the specified limit. As for the elevated concentrations of lead and other trace constituents in storm water, no corresponding water quality problems were observed in the wells. The only documented impact on the groundwater system was the increasing/decreasing temporal trend in mineral quality which was attributed to the imported water replenishment sources.

San Fernando Basin. Health Effects Study data for the San Fernando Basin sampling sites were compared to historical well data on file with the Department of Water and Power (III-13) and data from NPDES Reports for the Los Angeles/Glendale Water Reclamation Plant (III-14, III-15). Examination of the DWP well data indicated general agreement between the two data sets. Concentrations of trace constituents were in compliance with drinking water standards. Additionally, the overall mineral quality of the Hollywood well field was lower than the quality of the Pollock well field with the exception of nitrate concentrations. The historical data for the Pollock wells also substantiated the anomaly observed for one of the Health Effects Study samples regarding the lower than expected concentrations of mineral constituents as previously discussed.

Health Effects Study data were also in general agreement with data obtained from NPDES Reports for the Los Angeles/Glendale WRP. Monthly analyses for fluoride and quarterly analyses for cadmium and nickel showed concentrations which exceeded permit requirements. In the case of cadmium, the limit was equivalent to the primary MCL while for fluoride, below the MCL. Equivalent concentrations for each of the three constituents were observed in the Health Effects Study samples. A joint task force has been established by the City of Los Angeles to resolve the apparent industrial waste problem occurring at the Los Angeles/Glendale WRP to bring the treatment plant in compliance with permit requirements. Excessive chromium concentrations in the Los Angeles/Glendale effluent were not a common occurrence based on data in the NPDES Reports in contrast to the one Health Effects Study sample above specified limits. Total coliform concentrations were comparable to the concentrations observed in the study samples. However, it should be noted that the average monthly plant concentrations were lower (2.5 MPN/100 mL) than the average concentration for the study samples, with only two incidences reported of noncompliance with the 7-day median requirement of 2.2 MPN/100 mL. No corroborative data for the dry weather runoff samples were available.

Anaheim Forebay and Talbert Gap. Health Effects Study data for the Anaheim Forebay wells, Talbert Barrier observation wells and Water Factory 21 were compared to data available from the Orange County Water District's groundwater monitoring reports (III-3, III-4) and from an EPA/OCWD Report which presented the results of a four-year study on the operational aspects of Water Factory 21 (III-2). Of the four Anaheim Forebay wells sampled for the study, two were part of the OCWDs intensive groundwater monitoring program (Yorba Linda Well #11 and Anaheim Well #22). Monitoring data available for the wells were comparable to the corresponding Health Effects Study data presented in Table III-8 and Appendix A. Examination of the data demonstrated that for those constituents of health concern, concentrations not only complied with drinking water standards, but also were at or below analytical detection limits. In the latter case, the one exception was nitrate which ranged from 3 to 4 mg/L. Historical levels of nitrate reported in the Anaheim Forebay were generally within this range although higher concentrations were reported elsewhere in the basin. As in the case of the Montebello Forebay, the contributions of nitrate from fertilizer applications made it impossible to use nitrate as an indicator of the impacts of groundwater recharge, which in Orange County occurred incidentally as the result of upstream wastewater discharges into the Santa Ana River.

Health Effects Study data collected for Water Factory 21 were comparable to the extensive data presented in the EPA/OCWD Report. The occurrence of high nitrate concentrations in the activated carbon effluent was resolved when the influent source to the facility was no longer nitrified. In terms of reliability, the geometric mean concentration of all contaminants in the effluent from activated carbon treatment met the primary drinking water standards.

The Santa Ana Regional Water Quality Control Board and the State Department of Health Services have established requirements for the quality of the injection water produced by Water Factory 21. For most contaminants regulated by the requirements, maximum contaminant levels have been set at concentrations in agreement with primary and secondary drinking water standards. Maximum contaminant levels have also been established for specific conductance, ammonia, total nitrogen and boron. The geometric mean concentrations reported for all constituents were well below the specified MCLs. Specifically, no violations of lead or iron were reported in the injection water in contrast to the excess concentrations observed in the Health Effects Study data collected from the two observation wells (M-10 and M-12). Examination of detailed chloride, ammonia, color and coliform data collected for the injection water and observation wells indicated that the intensive data were in general agreement with the Health Effects Study data, with no significant impacts on water quality resulting from the injection operation.

VIRUS SAMPLING

Another potential health concern associated with groundwater replenishment is the possibility of virus transmission by the percolation or injection of wastewater. Although more than 100 types of enteric viruses are discharged in human feces, very little is known regarding the significance of these pathogens as environmental pollutants. Waterborne outbreaks of viral disease are very difficult to document, primarily because infections caused by enteroviruses can easily be attributed to human contact or injestion of contaminated food (III-16). Incidents of viral contamination of groundwater supplies which occurred by accident or as the result of intentional reuse (replenishment and irrigation) have been reported (III-17). In each case, a poorly treated or non-treated wastewater was implicated as the source of contamination. A literature review, which discusses these cases of contamination in more detail, is presented in Appendix B.

Based on the information reviewed, three general observations can be made regarding the potential for viral contamination by reuse. First, and most important, it appears that viruses do migrate through the soil into groundwater supplies. The extent of virus migration is dependent on the physical and chemical characteristics of the soil and solute. Although mitigation (adsorption) may occur given the proper conditions, soil cannot generally be considered as a dependable barrier against viral contamination. The second observation is that if viruses do adsorb to soil particles, they may desorb. This can occur after a rain storm or the application of any other low-ionic strength water and could potentially result in the appearance of transient spikes of relatively high virus concentration. The third and final observation is that the traditional indicators of fecal pollution such as coliform bacteria, do not necessarily provide adequate indices of viral contamination. Consequently, satisfactory data for bacterial indicators do not guarantee the absence of virus in groundwater.

The significance of these observations to water reuse in general and groundwater replenishment in particular, is that if the potability of the impacted water source is of concern, viruses should be reliably eliminated from the wastewater during treatment. A conservative approach would likewise dictate that the soil be considered only as a secondary barrier to viral migration and not as a primary means of removal or mitigation.

Such is the case in the Los Angeles and Orange Counties area where the reclaimed water used for replenishment (and other non-potable uses) is treated to the extent that it is considered to be "virus-free", i.e., no detectable virus. To confirm this assumption, the treatment plants within the study area (with the exception of the San Fernando Basin) were characterized for virus in a program separate from the water quality characterizations discussed in the previous section. Disinfected and nondisinfected effluent samples were collected at different stages of treatment from the Sanitation Districts' Whittier Narrows, San Jose Creek, and Pomona WRPs and from the Orange County Water District's Water Factory 21. Non-disinfected samples were collected to establish baselines for determining relative virus removal rates and to serve as positive controls for the virus sampling methods.

In addition, samples were collected from wells in the Montebello Forebay and Anaheim Forebay for virus and coliform assay. For the Montebello Forebay, this work was conducted to evaluate the impacts, if any, of the Whittier Narrows recharge operation. Because of the length of time required for the percolated water to reach a well, it was assumed that any impacts observed could be attributed primarily to the disinfected secondary effluent spread prior to 1977-78, and in some instances to a blend of disinfected secondary and tertiary effluents. Nine of the ten wells used for the water quality characterizations were evaluated; Well 1621MM was not included in the sampling program because its discharge flow was too low to accommodate the virus sampling apparatus. For the Anaheim Forebay, virus sampling was conducted both to evaluate background levels and to determine the impacts of incidental replenishment attributable to the spreading of wastewater in base flows of the Santa Ana River. The four wells chosen for the water quality characterization program were used for the virus sampling program. High volume coliform sampling was conducted for both study areas to provide more sensitive data than obtained using conventional sampling methods.

Methods

A complete discussion of the sampling and assay methods used for the virus and coliform testing program has been included as Appendix C. In summary, samples collected for virus assay were first concentrated using a truck-mounted, portable virus concentrator developed by the Los Angeles County Sanitation Districts for use in this study (III-18, III-19). The unit was a flow-through membrane filter adsorption system which incorporated automatic pH adjustment and aluminum addition during sample collection. It was capable of concentrating up to 1,000 gallons of well water and 300 to 500 gallons of wastewater with average virus recoveries of 83 percent and 42 percent, respectively, as determined with seeded polio virus.

Viruses were eluted from the filters using a three percent beef extract solution. The subsequent one liter eluant was reconcentrated to a final volume of approximately 10 mL by the organic flocculation method (III-20). Well water and final effluent concentrates were assayed on three cell lines (Buffalo Green Monkey Kidney, Primary African Green Monkey Kidney, and RD) using a liquid overlay technique. Each concentrate was split and the halves were tested during separate assays. Cells were periodically examined microscopically for cytopathic effect (CPE) after a period of two weeks. Cultures exhibiting viral CPE were passed to fresh cells for confirmation. Cultures which were negative after the first two weeks were frozen, thawed and the lysate was reinoculated onto fresh cells. These blind passes were again examined for CPE for a period of two weeks.

Non-disinfected primary, secondary, and tertiary effluent samples were assayed by the plaque method on monolayers of Buffalo Green Monkey Kidney cells. Plaques were picked and confirmed by passage in tube culture.

For the large volume coliform sampling, 20 liter well water samples were collected, transported to the laboratory and pressure filtered through a Whatman GF/F filter overlaid with diatomaceous earth. The filter and diatomaceous earth were homogenized and innoculated into multiple tube dilution tests for coliforms. The MPN tests were run as described in Standard Methods (III-5).

Stringent operational procedures were utilized for all laboratory portions of the sampling program. A special laboratory was designed for the study consisting of a clean room used only for potable samples and a separate room used for all other virus sample processing. A description of the laboratory facilities and operational procedures has been included in Appendix C.

Results

Virus data for each sampling point have been presented in Appendix D. A total of 223 wastewater samples collected from the Whittier Narrows, San Jose Creek, Pomona, and Water Factory 21 WRPs were concentrated for virus assay during the period January 1979 through October 1981. The numbers and types of samples collected are summarized in Table III-9. No viruses were detected in any of the disinfected tertiary effluent samples (dual media, activated carbon, and advanced waste treated (AWT) activated carbon). However, viruses were routinely isolated from non-disinfected wastewater samples as shown in Table III-9. Median concentrations as determined by statistical probability analysis (III-21, III-22) ranged from 230 to 1,600 pfu/gal for unchlorinated primary effluents and from 0.43 to 65 pfu/gal for unchlorinated secondary effluents. The median virus concentration for the unchlorinated activated carbon effluent at the Pomona WRP was 0.52 pfu/gal. Relative removals for each treatment step are shown in Figure III-4.

A total of 110 groundwater samples were collected from the Montebello and Anaheim Forebays during the period March 1980 through May 1981. The number of

TABLE III-9

WATER RECLAMATION PLANT VIRUS SAMPLING SUMMARY

Sample Type	Pomona WRP		San Jose Creek WRP		Whittier Narrows WRP		Water Factory 21	
	Number of Samples	Median a/ Concentration pfu/1000 gal	Number of Samples	Median a/ Concentration pfu/1000 gal	Number of Samples	Median a/ Concentration pfu/1000 gal	Number of Samples	Median a/ Concentration pfu/1000 gal
Unchlorinated Effluent								
Primary	13	2.3×10^5	8	1.6×10^6	8	7.6×10^5	-	-
Secondary	12	6.5×10^3	14	5.5×10^2	9	5.6×10^2	11d/	4.3×10^2
Tertiary	12b/	5.2×10^2	-	-	-	-	-	-
Chlorinated Effluent								
Tertiary	33b/	<2	43c/	<2	38c/	<2	10e/	<1

a/ Virus concentrations expressed as probability medians, plaque forming units per 1,000 gallons.
b/ Pomona tertiary effluent receives activated carbon filtration.
c/ San Jose Creek and Whittier Narrows tertiary effluents receive dual media filtration.
d/ Influent to Water Factory 21.
e/ Activated carbon effluent stream from Water Factory 21 which has received additional advanced treatment.

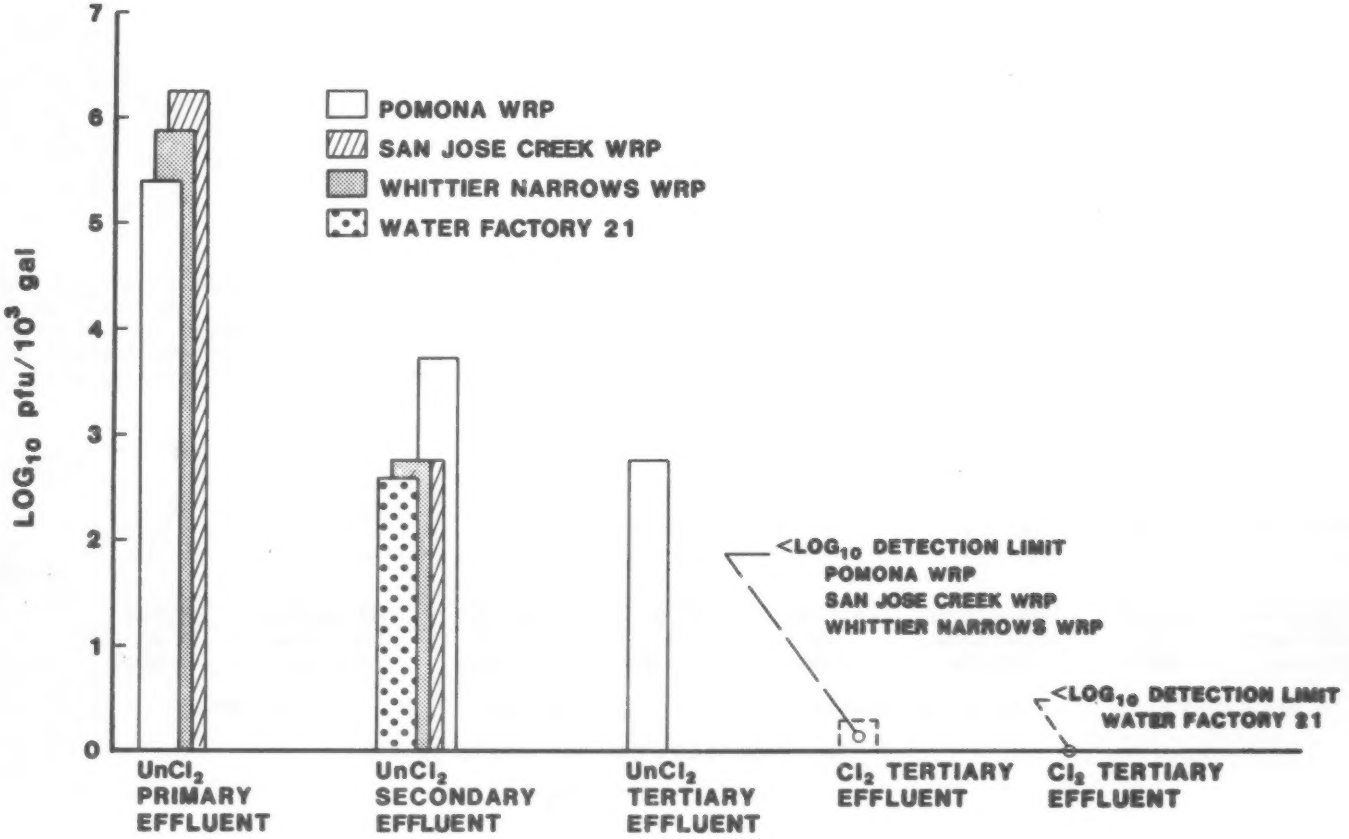


FIGURE III-4
RELATIVE VIRUS REMOVAL EFFICIENCIES FOR WRPs

samples collected from each well site is listed in Table III-10. No viruses were detected in any of the well samples. One Montebello Forebay well sample (Well 1514A, 6/3/80) yielded an amoeba isolation of the genus Acanthamoeba. Positive identification was performed by the California Department of Health Services Laboratory at Berkeley. From a longterm viewpoint the health significance of this single incident is unknown. Free living amoebae of this type are ubiquitous in nature and have been reported as contaminants of plate or cell cultures (III-23). Acanthamoeba has also been implicated as one of the etiologic agents producing Primary Amebic Meningoencephalitis (PAM) in man (III-24). Although the organism can be acquired by contact with fresh water, the epidemiology is somewhat obscure. Most outbreaks of PAM have occurred as the result of swimming in warm water lakes, heated pools, and mineral baths.

Coliform concentrations in the well waters as determined by grab samples collected at the time of virus sampling were very low; the majority of samples yielding concentrations less than 2 MPN/100 mL. During the latter part of the study, large volumes of unchlorinated well water samples were concentrated for coliform testing, the results of which are shown in Table III-11. Coliform concentrations for the wells ranged from <0.006 MPN/100 mL to ≥ 77 MPN/100 mL. The median concentration as determined by probability analysis was 0.055 MPN/100 mL (see Figure III-5).

Discussion

The virus results reported here clarify several points with regard to water reuse by groundwater recharge and the potential health hazards associated with virus contamination. First, it is evident that reliable and effective treatment of wastewater intended for reuse reduced the risk of contamination to negligible levels. Of the 174 disinfected tertiary effluent samples assayed for this study, none contained virus. This is in direct contrast to the incidents of viral contamination of groundwater reported in the literature which were caused by the application of poorly treated wastewaters. For those cases, virus concentrations in disinfected secondary and tertiary effluents were comparable to concentrations found in non-disinfected primary effluents sampled for the Health Effects Study.

With regard to the effectiveness of different treatment processes, the results showed that virus concentrations were significantly reduced with each stage of treatment. Primary and secondary unit processes achieved 1- to 3-log reductions in viral concentrations. On-line filtration (dual media and activated carbon) and advanced waste treatment combined with chlorination achieved 5-log or greater reductions in virus as previously demonstrated elsewhere (III-25, III-26). It is important to note that disinfection was the critical treatment step in achieving a "virus free" effluent as demonstrated by the median concentration of 0.52 pfu/gal found in unchlorinated tertiary effluents.

Based on the results from the Montebello Forebay well samples it appears that the past replenishment practice has not adversely impacted the quality of the area's groundwater. No viruses were found in any of the 90 groundwater samples, 87 percent of which were unchlorinated. Given that the current level of treatment of reclaimed water is higher than that previously applied, it is

TABLE III-10

GROUNDWATER VIRUS SAMPLING SUMMARY

Well Site	Sample[a] Type	Number of Samples	Average Sample Volume gal	Virus[b] Results
Montebello Forebay:				
Well 1514 A	$UnCl_2$	10	1,000	Neg
Well 1562 E	$UnCl_2/Cl_2$[c]	6/2[c]	732/1,000	Neg
Well 1566 A	$UnCl_2$	11	1,000	Neg
Well 1580 J	$UnCl_2$	11	1,000	Neg
Well 1591 H	$UnCl_2$	10	821	Neg
Well 1620 GG	$UnCl_2$	10	1,000	Neg
Well 2907	Cl_2	10	1,000	Neg
Well 2947 Q	$UnCl_2$	10	1,000	Neg
Well 2958 A	Cl_2	10	1,000	Neg
Anaheim Forebay:				
Anaheim Well 22	$UnCl_2$	5	1,000	Neg
Anaheim Well 27	$UnCl_2$	5	1,000	Neg
Anaheim Well 29	$UnCl_2$	5	1,000	Neg
Yorba Linda Well 11	Cl_2	5	920	Neg

[a] Sample types collected included $UnCl_2$ = unchlorinated and Cl_2 = chlorinated well waters.

[b] Neg = negative, detection limits ranged from 1 to 2 infective units per 1,000 gallons.

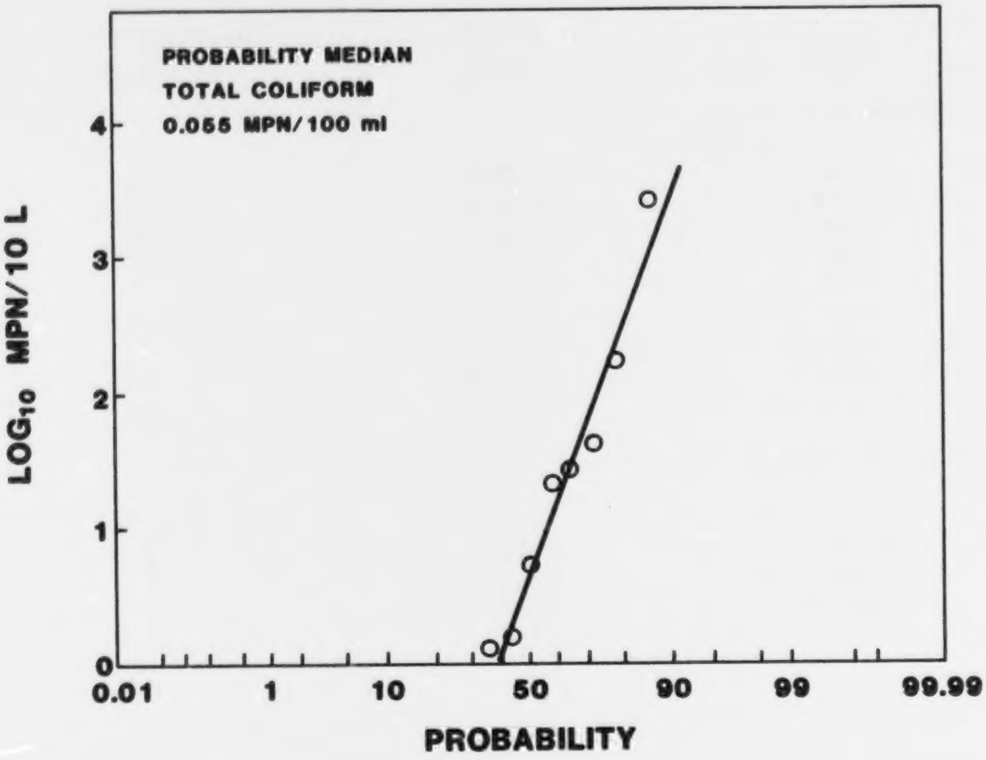
[c] The on-site chlorinator was only in operation for two of eight samplings.

TABLE III-11

HIGH VOLUME COLIFORM TESTING RESULTS FOR UNCHLORINATED GROUNDWATER

Well	Sample Date	Total Coliform MPN/100 mL
Montebello Forebay:		
1591 H	3-12-81	< 0.006
1514 A	4-14-81	0.016
1591 H	4-16-81	< 0.006
2947 Q	4-22-81	< 0.006
1620 GG	5-06-81	≥ 77
1566 A	5-08-81	0.013
1580 J	5-13-81	28
1591 H	5-27-81	0.055
1620 GG	5-29-81	< 0.006
Anaheim Forebay:		
Anaheim 29	3-10-81	0.43
Anaheim 29	3-20-81	0.22
Anaheim 22	4-01-81	0.27
Anaheim 27	4-07-81	1.7

FIGURE III-5 RESULTS OF LARGE VOLUME COLIFORM SAMPLING OF UNCHLORINATED GROUNDWATER



apparent that any future concerns over virus transmission by recharge should be minimized. Negative virus results obtained for the Anaheim Forebay wells should theoretically negate concerns over the possibility of adverse impacts from incidental recharge. Although observation wells were not monitored for this study, the level and reliability of treatment provided by Water Factory 21 should also eliminate concerns over virus transmission via injection, as well as the future use of a Water Factory 21-type effluent for spreading in the Anaheim Forebay.

SUMMARY AND CONCLUSIONS

Results obtained from the water quality evaluations have demonstrated that the use of reclaimed water for groundwater replenishment in the Montebello Forebay has not adversely impacted the potability of the area's groundwater in terms of inorganic chemical and microbiological contaminants. Reclaimed water and imported waters used for replenishment have traditionally met health-related primary drinking water standards and most aesthetics-related secondary standards as has the groundwater impacted by replenishment. Well water concentrations in excess of secondary standards were not attributable to any of the replenishment waters; the variable pattern of concentrations above the standards appeared to be a local water quality phenomenon. As for storm water, concentrations of many trace constituents, particularly lead, have historically exceeded specified limits. No corresponding water quality problems have been observed in the wells, suggesting that dilution and/or soil attenuation have occurred. The only water quality impact on the groundwater system resulting from the replenishment operation has been a temporal trend in mineral levels caused by percolation of imported waters.

From a microbial viewpoint the results were similar. No viruses were detected in any of the Montebello Forebay groundwater samples demonstrating that the past replenishment practice (using disinfected secondary effluent) has not adversely impacted the wells. Reclaimed water samples indicated that the present level of tertiary treatment combined with disinfection reliably produced a "virus-free" effluent, thus providing an added measure of safety for current and future replenishment.

Based on these results, it would appear that in terms of inorganic chemical and microbial constituents, the existing replenishment practice could be expanded without modification. At present, the treatment plants supplying reclaimed water for replenishment routinely produce effluents containing inorganic chemical and microbial constituents at levels that pose no acute or chronic health threat. There have been concerns expressed over the impacts of plant upsets; i.e., situations in which the treatment facilities are not in full operation and therefore are producing only partially treated water. Contingency procedures have been established for those situations which allow for improperly treated flows to be diverted from the spreading grounds. Moreover, historical records have shown these episodes to be rare; very few plant upsets have occurred during the 20 years the reuse program has been in operation. Consequently, adequate measures exist to insure that the reclaimed water used for groundwater replenishment is of the highest quality possible. Results from the other designated study tasks remain to be evaluated in subsequent chapters before definitive conclusions can be made regarding project expansion.

As for the San Fernando Basin, results from groundwater sampling have demonstrated that background concentrations of inorganic chemical constituents in the Hollywood and Pollock well fields are in compliance with drinking water standards. There were differences between the two well fields in terms of mineral quality with higher concentrations reported in the Pollock wells. It is possible that this condition may have resulted from the percolation of dry weather runoff in the Los Angeles River which appeared to be high in mineral content, based on evaluations of limited data collected for the study.

Effluent samples from the Los Angeles/Glendale WRP did not comply with specified cadmium requirements for drinking water. This problem, considered to be of industrial origin, may be resolvable through the implementation of more stringent source control measures. Should the reclaimed water produced by the Sepulveda WRP be similar in quality to that of the Los Angeles/Glendale WRP, it will be necessary to determine whether or not it is critical to insure that the heavy metal concentrations in the final effluent routinely comply with MCLs prior to reuse. Experience from recharge of storm runoff in the Montebello Forebay would indicate that no problems have resulted from percolation of a source water which historically has contained trace constituents at concentrations above allowable limits. However, it should be recognized that there is no control over the quality of storm water replenishing the basin. The same is not true for reclaimed water. Thus, if the problem can be corrected by source control or operational modifications in existing treatment, then a conservative approach would dictate that the effluent meet standards prior to use.

No data were collected on the virological characteristics of the Los Angeles/Glendale WRP. In lieu of virus sampling, proper operation of this and similar facilities should insure the production of "virus free" effluents as verified by the negative virus data obtained for the Sanitation Districts on-line filtration plants.

Data obtained for the Anaheim Forebay wells were also in compliance with drinking water standards. No viruses were found in any of the chlorinated or unchlorinated well samples. These results demonstrate that incidental replenishment with wastewater has had no apparent effects on groundwater quality.

Data obtained for Water Factory 21 were in agreement with the extensive data base compiled by the Orange County Water District. Results demonstrated that concentrations of inorganic constituents reliably complied with drinking water standards. No measurable levels of virus were detected in effluent samples. Inorganics data collected for observation wells yielded similar results with no apparent impacts from the injection operation. Production of an effluent similar in quality to that produced by Water Factory 21, (as envisioned for the proposed Anaheim Forebay WRP) should negate any risks for the transmission of harmful agents via surface percolation.

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CHAPTER IV

TOXICOLOGY AND TRACE ORGANICS

INTRODUCTION

The trace organic content of potable water supplies has been a major concern in considerations of environmental impacts on human health. Chronic effects, especially those manifested as carcinogenic, mutagenic, or teratogenic responses are of primary importance and have been the focus of several epidemiologic and toxicological studies (IV-1-IV-8). During the 1970s many surveys were conducted to assess possible adverse impacts of trace organics on human health and the scope of organics contamination in general. These included surveys of U.S. drinking waters for halogenated organics (IV-9) and national surveys which attempted to compile known information on the identity and toxicology of individual compounds in water supplies (IV-10-IV-14). At the start of the Health Effects Study, approximately 1,300 different organics had been identified in drinking water in about 5,500 individual reports (IV-15). The probable origins, sources, and health significance of these compounds were known with varying degrees of accuracy, and in many instances, their occurrence was local or regional in nature. A common observation in such studies was that a major portion of the organics present remained unidentified, as did the possible health significance of the material.

The uncertainty regarding the mixture of organic residues in drinking water has continued to create concern among health officials in view of the possible chronic health impacts which might be caused by widespread use of reclaimed wastewaters for augmentation of drinking water supplies (IV-16). The complexity of organic mixtures in wastewaters has been reported (IV-17, IV-18), and while only a relative handful of the myriad components was identifiable, the probability that these kinds of mixtures were stable and contained a significant portion of halogenated organics was discussed (IV-19-IV-21).

The Toxicology/Trace Organics portion of the Health Effects Study proposed to build on the results of previous reports, and by combining state-of-the-art chemical and toxicology methods, proposed to assess the impact of percolating reclaimed water and other surface supplies on groundwater potability. The study design, shown schematically in Figure IV-1, consisted of three areas of work. First, the groundwater, reclaimed water and various other surface supplies from each of four study areas (see Figures II-3, III-1, III-2, III-3) were surveyed for the presence of specific organics which have known or suspected long-term health effects. These target organic analyses were conducted by gas chromatography/mass spectrometry (GC/MS) methods. Second, the relative toxicity of organic residues isolated and concentrated from the test sites was estimated. Emphasis in this area of concern was on mutagenic/carcinogenic response. All samples were bioassayed using the Ames Salmonella microsome mutagen test (IV-22) and a selected subset was assayed in a mammalian cell transformation test (IV-23). Third, using the Ames test as a criterion, mutagenic fractions of organic residues of selected samples were isolated and analyzed in detail in

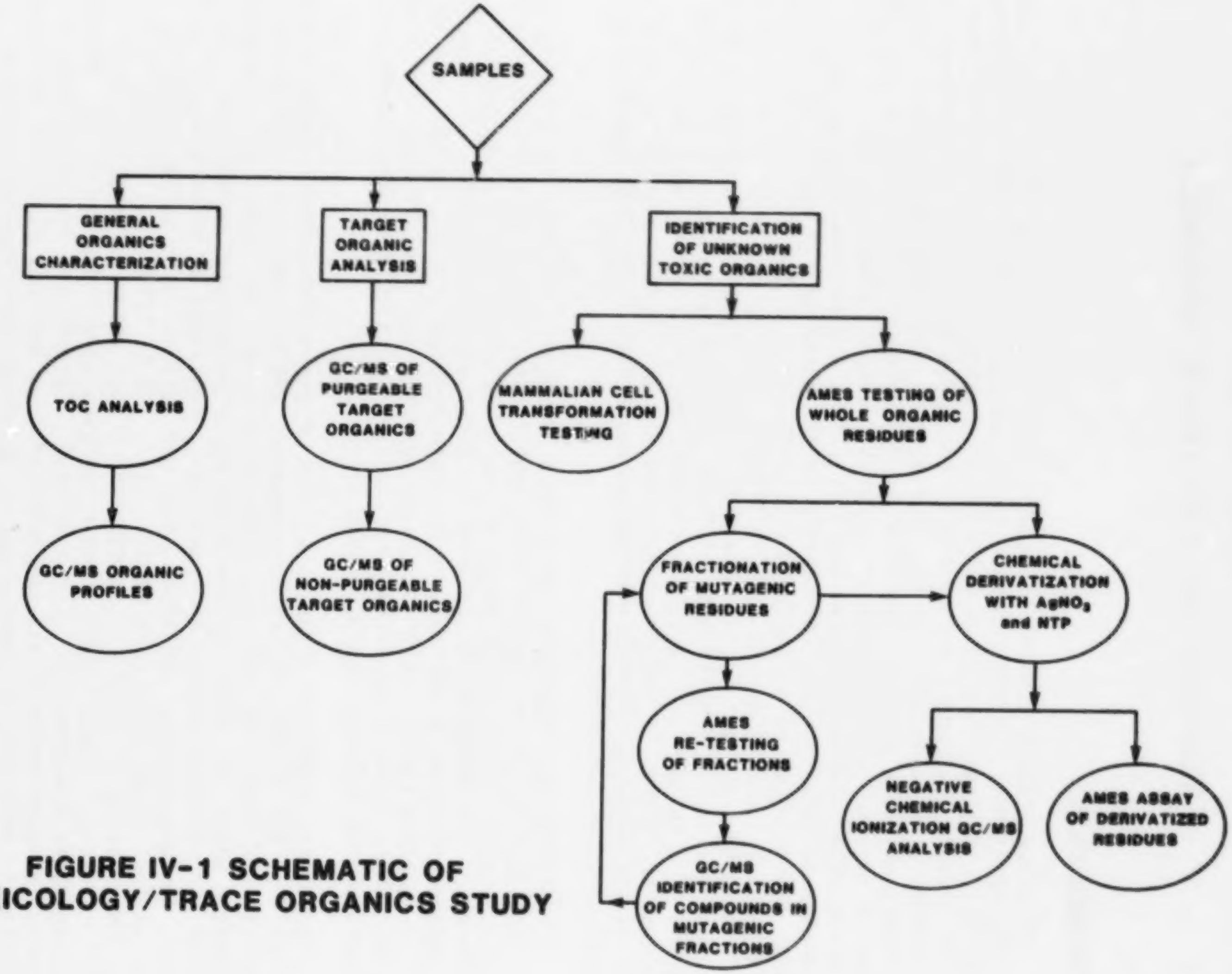

SAMPLES
GENERAL ORGANICS CHARACTERIZATION
TARGET ORGANIC ANALYSIS
IDENTIFICATION OF UNKNOWN TOXIC ORGANICS
TOC ANALYSIS
GC/MS ORGANIC PROFILES
GC/MS OF PURGEABLE TARGET ORGANICS
GC/MS OF NON-PURGEABLE TARGET ORGANICS
MAMMALIAN CELL TRANSFORMATION TESTING
AMES TESTING OF WHOLE ORGANIC RESIDUES
FRACTIONATION OF MUTAGENIC RESIDUES
CHEMICAL DERIVATIZATION WITH AgNO3 and NTP
AMES RE-TESTING OF FRACTIONS
GC/MS IDENTIFICATION OF COMPOUNDS IN MUTAGENIC FRACTIONS
NEGATIVE CHEMICAL IONIZATION GC/MS ANALYSIS
AMES ASSAY OF DERIVATIZED RESIDUES

FIGURE IV-1 SCHEMATIC OF TOXICOLOGY/TRACE ORGANICS STUDY

order to characterize the molecular nature of unknown components which may have contributed to the mutagenicity. This part of the study utilized a number of chemical fractionation techniques, selective derivatizations, and mass spectrometry for the molecular characterizations. This overall study approach was designed in an effort to focus maximum attention on compounds of known health significance and on only those unknowns which, because of their specific chemical or biological nature, were suspected of being health significant. The pivotal concept, based on the results of several other analytical studies (IV-17, IV-19, IV-24-IV-26), was that the majority of the thousands of organic components present in waterborne organic residue mixtures were apparently natural products and homologous series of compounds of doubtful health significance. Therefore, it became desirable from an analytical standpoint, inasmuch as practicable, to isolate only those compounds having specific health-suspect properties for the difficult task of molecular identification or characterization.

Methods selection and development, from the outset and continuing through the study, were based on currently available equipment. Ensuing sections of this chapter will discuss the principles and development of methods which are necessary for explanation and understanding of experimental results. For all sections, routine procedures are referenced as appendices for detailed examination of methods employed.

SAMPLING AND PRESERVATION

The effective use and interpretation of chemical and biological assays for the detection of target compounds or specific classes of organics requires sampling methodology which can isolate a representative sample of the organic mixture present. This is a formidable task in that such mixtures comprise a virtual continuum of chemical and physical properties. Most studies have concentrated either on identification of components in the organic fraction which are volatile enough to be analyzed by gas chromatography (GC), or on the bioassay of the less volatile residues which remain after concentration and subsequent evaporation to dryness. The volatile compounds identified by GC methods (including mass spectrometric detection, GC/MS) represent less than 20 percent of the dissolved organic carbon (DOC) present (IV-11). The few compounds identified from the non-volatile group have been naturally occurring hydrophiles such as amino acids and carbohydrates (IV-27) which are not likely to elicit mutagenic or carcinogenic responses in bioassay systems. Much of the remaining mass is known to be composed of humic and fulvic acids. It is reasonable to assume that most of the non-volatile compounds in this group are water soluble and are polar or ionic at neutral pH.

A variety of approaches has been reported for concentrating unknown trace organic mixtures from water. These include solvent extraction (IV-28, IV-29), low temperature vacuum distillation (IV-30), reverse osmosis (RO) (IV-31-IV-33), adsorption (IV-34-IV-38), and purge and trap methods (IV-39). The latter is a necessary adjunct to any of the others, since it allows quantitation of compounds which are too volatile to be retained during normal sample manipulation; EPA purge and trap methods were chosen for the analysis of purgeable target organics (PTO) in this study.

Isolation of sufficient amounts of representative non-purgeable organic residues for subsequent chemical and biological assay has typically been attempted by RO (IV-40, IV-41) or resin adsorption (IV-42, IV-43). Although each of these methods can present certain operational drawbacks and may discriminate against particular compound classes, macroporous resins of the ionic and non-ionic types were chosen for this study because they have been well characterized in the literature and they present advantages in terms of sample flow rates and efficient yields of representative mixtures of organics. The development and use of a resin-based concentration system for this study has been described in detail in the literature (IV-43, IV-44). The design of the concentration system was based on published findings which suggested that resins could be used as medium-and high-performance liquid chromatographic media if the resin beads were ground and sieved to < 75 μm (IV-45-IV-50). Capacity factors were reported for a wide range of organic molecules for XAD resins (IV-45-IV-51), as were aqueous solubilities and recommended ratios of sample volume to resin weight (IV-51). The common misconception that organic solutes remain adsorbed by a few grams of resin while many liters of water are continually passed through the resin bed was discussed in relation to projects which attempted to use bead resin columns to concentrate organics from water supplies (IV-52).

Leehneer and Huffman (IV-38) described the combined use of ionic macroreticular resins and XAD resins for classifying organic solutes in water. In this classification scheme, hydrophobic solutes were adsorbed on ionic, non-polar macroporous resins like XAD-4, while hydrophilic solutes were adsorbed on macroporous ion-exchange resins.

Several carefully controlled studies have evaluated the recovery of standard compounds from water samples by XAD bead resins in open columns (IV-34-IV-37). Recoveries for more than 100 compounds were generally good (65 to 107 percent) in these studies, provided certain precautions were taken. In one study (IV-34), XAD-2 was shown to recover more than twice the amount of gas chromatography detectable material from drinking water than could be recovered by granular activated carbon (GAC), and recovery of standards with XAD-2 was equal or superior to GAC for 67 compounds.

The concentration system designed for the study (IV-44) was based on the principles of preparative high performance liquid chromatography (HPLC). Objectives of the design included negligible sample contamination, efficient adsorption of a wide range of organics from large volumes (up to 200 L) of water at high flow rates, efficient elution, and a representative and sufficient mass of residue for a spectrum of chemical and biological evaluations. The high volume concentrator consisted of a high pressure Teflon diaphragm pump followed by a series of stainless steel columns packed with 45-75 μm macroporous resins in the following order: anion-exchange (MP-1), cation-exchange (MP-50), nonpolar nonionic (XAD-2), and polar nonionic (XAD-7). The operation of this system is described briefly elsewhere in this chapter, and in detail in Appendix E.

Total Organic Carbon and Purgeable Target Organics

Grab samples for total organic carbon (TOC) and purgeable target organic (PTO) analyses were collected at each location (see Figures III-1, III-2, III-3) in 125 mL crimp-top septum vials (IV-39). Ninety samples were collected during the period February 1979 to February 1981. Well water samples were taken from spigots at the well head; surface samples were pumped, by means of a stainless steel-ceramic piston pump, through Teflon tubing into the vials. Care was taken to fill the vial without air bubbles, and each vial was capped with a Teflon-backed septum and aluminum cap immediately after filling. Chlorinated samples were dechlorinated by placing a few sodium thiosulfate crystals in the vial prior to sampling in order to halt production of trihalomethanes (THM) at the time of sampling. Samples were stored at 0-4°C until analytical processing was initiated.

Non-Purgeable Organic Residues

Ninety samples for non-purgeable organic residue (NPOR) analyses were collected at the same time as the TOC and PTO samples. Larger volumes (10 to 200 L) were collected for NPOR samples, which usually required 2 to 4 hours of sampling time. Samples were pumped or forced (well head spigot pressure) through a Carborundum K-27 3.0 µm filter into glass or stainless steel containers and delivered to the laboratory for immediate concentration. Volumes of 10 to 20 L were obtained for sample Nos. 1-17, 40, 80, 87-90; volumes of 100 to 200 L were collected for all others. The 10 to 20 L samples were concentrated on a small prototype (IV-44) of the high volume concentrator shown in Figure E-1, Appendix E. Detailed procedures for use of the concentrator are given in Appendix E. Samples were pumped (Teflon diaphragm pump) through the resin columns at a linear velocity of 0.2 cm/sec (250 mL/min on the high volume system) at approximately 1400 psi. Following the concentration step, the K-27 filter and resin columns were eluted with acetonitrile and saturated salt solution (ionic resins only); salt solutions were extracted at pH 1 or pH 11 with acetonitrile. Acetonitrile fraction volumes were reduced in Kuderna-Danish evaporators, and the concentrates were stored separately at -20°C until analysis. Care was taken to avoid evaporation to dryness. Proportional volumes of the concentrates were combined just prior to analysis, and the remaining concentrates were returned to the freezer. Within statistical limits of the Ames assay, this method of storage was determined to not affect the outcome of the mutagen test on 33 samples evaluated for change during the course of the study (see Appendix H).

Performance of the concentrator was evaluated in several ways. First, during concentration, column effluents were monitored by an ultraviolet (UV) detector/recorder in order to detect gross organic breakthrough; none was detected. Second, on a periodic basis, effluents were extracted, and the resultant concentrates were Ames tested for breakthrough of mutagens. As shown in Table IV-1, no significant mutagen breakthrough was detected. Third, between each sample, columns were cleaned by repeating the solvent elution sequence; as a spot-check, these column "blanks" were evaluated by GC/MS and Ames test to determine if sample carryover was occurring. In only one case was a slight carryover of organics from sample to blank observed. No significant mutagen carryover was detected, however, as demonstrated by examining data in Table IV-1. The appropriate GC/MS "blank" results for target organics are presented along with target organic results for all 90 samples in Table G.2, Appendix G.

The efficiency of the concentrator in removing organic residues from water samples was evaluated by measuring TOC before and after concentration of different sample types. These results, summarized in Table IV-2, suggest that an

TABLE IV-1

MUTAGENICITY BALANCE FOR SAMPLES AND BLANKS FROM RESIN CONCENTRATOR

Sample a/ Number	Sample Type b/	Resin Concentrate Rev/L c/		Resin d/ Blank Rev/L		Column e/ Effluent Rev/L	
		TA98	TA100	TA98	TA100	TA98	TA100
19	$UnCl_2$ 2°	100	<4100	< 60	<400	NA	NA
21	Cl_2 Well	60	220	NA	NA	< 90	< 330
22	$UnCl_2$ Well	150	870	NA	NA	< 90	< 330
23	$UnCl_2$ Well	130	590	< 80	<180	<210	< 480
26	$UnCl_2$ Well	< 20	<200	NA	NA	< 70	< 470
28	$DeCl_2$ 3°	2800	2700	NA	NA	< 90	< 330
39	Cl_2 Well	210	220	NA	NA	<100	< 600
53	$UnCl_2$ Well	430	820	< 20	< 90	NA	NA
64	Cl_2 R.O.	130	330	< 4	< 22	NA	NA
70	$UnCl_2$ Well	230	270	NA	NA	< 60	< 330
74	$UnCl_2$ Well	310	NA	8	NA	NA	NA

a/ For sample number reference, see Appendix I.

b/ $UnCl_2$ = unchlorinated; Cl_2 = chlorinated; $DeCl_2$ = dechlorinated; 2° = secondary effluent; 3° = tertiary effluent; R.O. = reverse osmosis effluent.

c/ Rev/L = revertants per liter.

d/ The resin blank consisted of repeating the solvent elution sequence after removal of sample from resin; NA = not analyzed.

e/ Column effluent sample taken by collecting 6L sample effluent saturating with NaCl and extracting at pH 1 and 11 with CH_3CN; NA = not analyzed.

TABLE IV-2

TOC REMOVALS FOR PROTOTYPE AND HIGH-VOLUME CONCENTRATORS

Sample Description	Volume Concentrated (L)	TOC Concentrator Influent (mg/L C)	Percent TOC Removal a/
Chlorinated well water	161	2.18	73
Chlorinated well water	17	1.52	53
Unchlorinated well water	170	0.53	30
Unchlorinated well water	200	1.11	68
Unchlorinated well water	180	1.80	69
Unchlorinated well water	180	1.06	86
Unchlorinated well water	178	0.45	60
Tertiary treated wastewater	16	12.0	66
Tertiary treated wastewater	97	19.4	81
Tertiary treated wastewater	19	13.9	76
Tertiary treated wastewater	100	5.1	77
Tertiary treated wastewater	95	15.3	80
Chlorinated secondary effluent	9.4	15.4	71
Chlorinated secondary effluent	95	17.6	81
Unchlorinated secondary effluent	95	12.7	73
State Project water	180	3.5	52
Colorado River water	100	7.0	84

a/ Calculated as $$\frac{[(\text{TOC concentrator influent}) - (\text{TOC concentrator effluent})]}{(\text{TOC concentrator influent})} \times 100$$

average of 70 percent organic removal can be expected for samples in the TOC range of 0.5 to 20 mg/L.

Recovery of organics with the concentrator was assessed by a series of experiments with reclaimed waters and drinking waters, which had been spiked with mixtures of standards. Results are presented in Appendix F, where 70 percent or greater recovery was achieved for most compounds. In general, these results were similar to those reported in the literature for standard recoveries with bead resins (IV-34-IV-37).

GENERAL ORGANIC CHARACTERIZATIONS

Classical methods of evaluating organic chemical burdens in aqueous environmental samples have included measures of gross organic content such as DOC, TOC, carbon-chloroform extraction (CCE), organic nitrogen, suspended matter, chemical and biochemical oxygen demand tests (COD, BOD), or other surrogate tests (UV absorbance, color). Although these tests have proven essentially useless in assessing specific human health hazards in potable water, such measures still find utility as descriptors of general water quality within a framework of more detailed chemical analysis. In this regard, TOC data for various sample types evaluated in the Health Effects Study are summarized in Table IV-3 for easy comparison of general organic content. As can be seen, the organic content in the different sample types (except for R.O. effluent) is in the order: storm runoff > reclaimed water > dry weather runoff > imported water > groundwater. However, the degree of overlap for these samples precludes a statement about the relative impacts of source waters on groundwater except to note that there may be a general attenuation of organics occurring between surface water and groundwater sources.

The more specific means of analyzing organics in water usually include GC and GC/MS techniques for the analysis of individual organics. Although these methods discriminate against components which cannot pass through a GC column, the relative amounts and complexity of organic mixtures can often be illustrated by examining GC profiles of different samples. Such is the case with the kinds of samples studied in this chapter. Figures IV-2 through IV-4 contain representative computer-reconstructed ion chromatograms obtained from GC/MS analysis of groundwater and surface supply residues in the four study areas. The ion current intensity (or area under the GC profiles) can be used to visually compare relative amounts of hydrocarbons in samples, and the complexity can be roughly assessed from the number of component peaks in each chromatogram. Each figure indicates the relative amounts of sample represented by the respective chromatograms. In the Montebello Forebay study area (Figure III-1), storm waters and reclaimed waters exhibited similar organic content and complexity while the profiles of the imported waters and groundwaters were less complex (Figure IV-2). For the San Fernando Basin area (Figure III-2), the dry weather runoff contribution to groundwater seemed apparent since the Los Angeles River catchment basin at the Headworks spreading grounds (Figure IV-3.A) is a primary surface percolation source affecting the Pollock well field (Figure IV-3.B). Dry weather runoff in the San Fernando Basin also appeared to contain higher concentrations of organics than reclaimed water and storm runoff in the Montebello Forebay area. Likewise, the well fields in the San Fernando Basin were of greater organic complexity than wells sampled in the Montebello Forebay

TABLE IV-3

SUMMARY OF TOC DATA FOR DIFFERENT SAMPLE TYPES IN THE FOUR STUDY AREAS

Location/Sample Type	TOC Range, mg/L
Montebello Forebay	
Reclaimed Water a/	5-19
Imported Water	3-6
Storm Water	12-19
Groundwater	0.3-5
San Fernando Basin	
Reclaimed Water b/	8-13
Dry Weather Runoff	6-8
Groundwater	0.3-1.4
Anaheim Forebay/Talbert Gap	
Reclaimed Water	
Activated Carbon Effluent c/	6.7
Reverse Osmosis Effluent d/	0.4-0.6
Forebay Groundwater	0.7-1.8
Observation Well Groundwater	0.5-3.6

a/ Includes data for chlorinated secondary and dechlorinated filtered effluents.
b/ Data for chlorinated filtered effluent.
c/ Data for chlorinated effluent.
d/ Data for unchlorinated and chlorinated effluent.

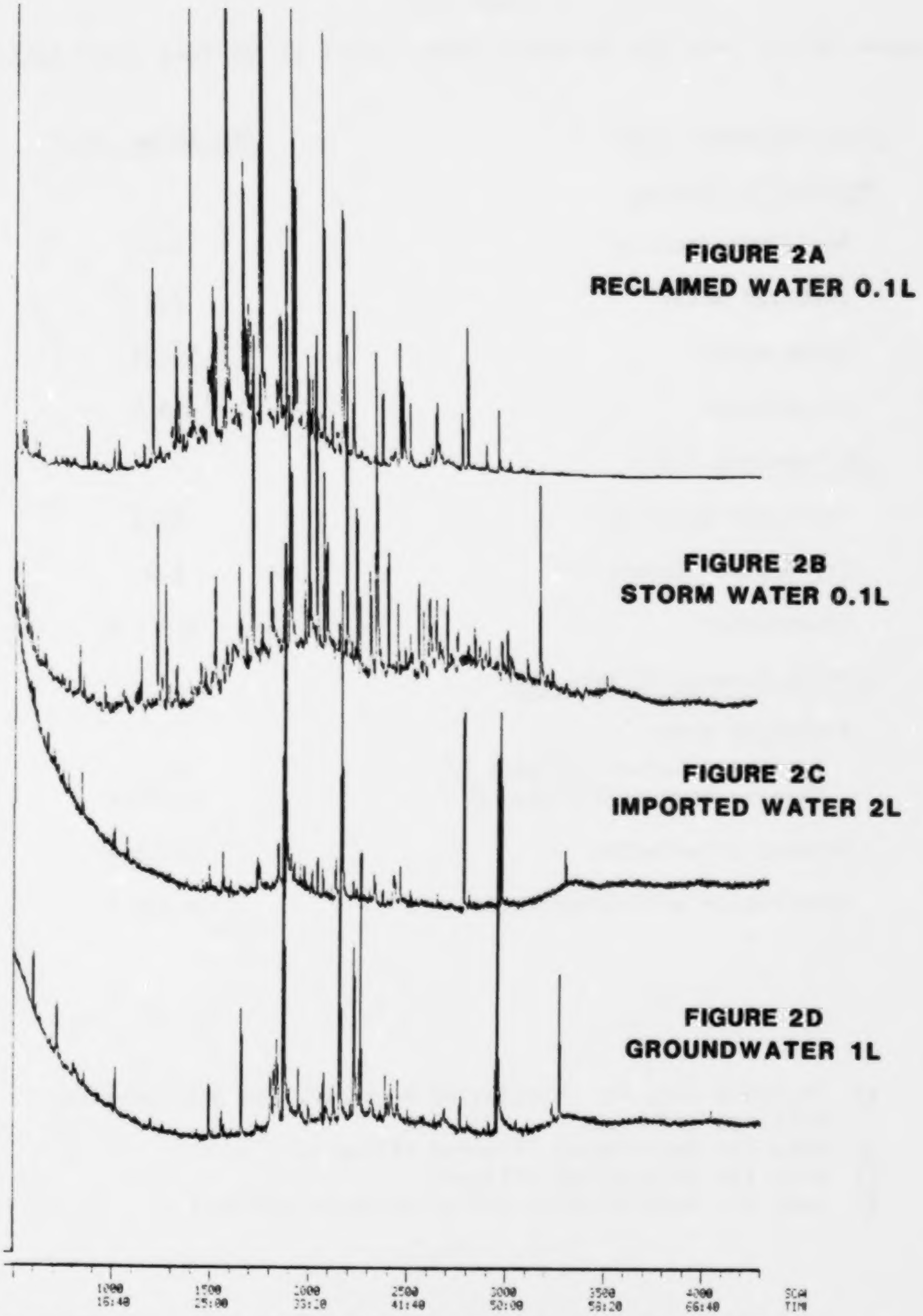


FIGURE IV-2 COMPARISON OF RELATIVE AMOUNTS OF CHROMATOGRAPHABLE ORGANICS IN MONTEBELLO FOREBAY SAMPLES

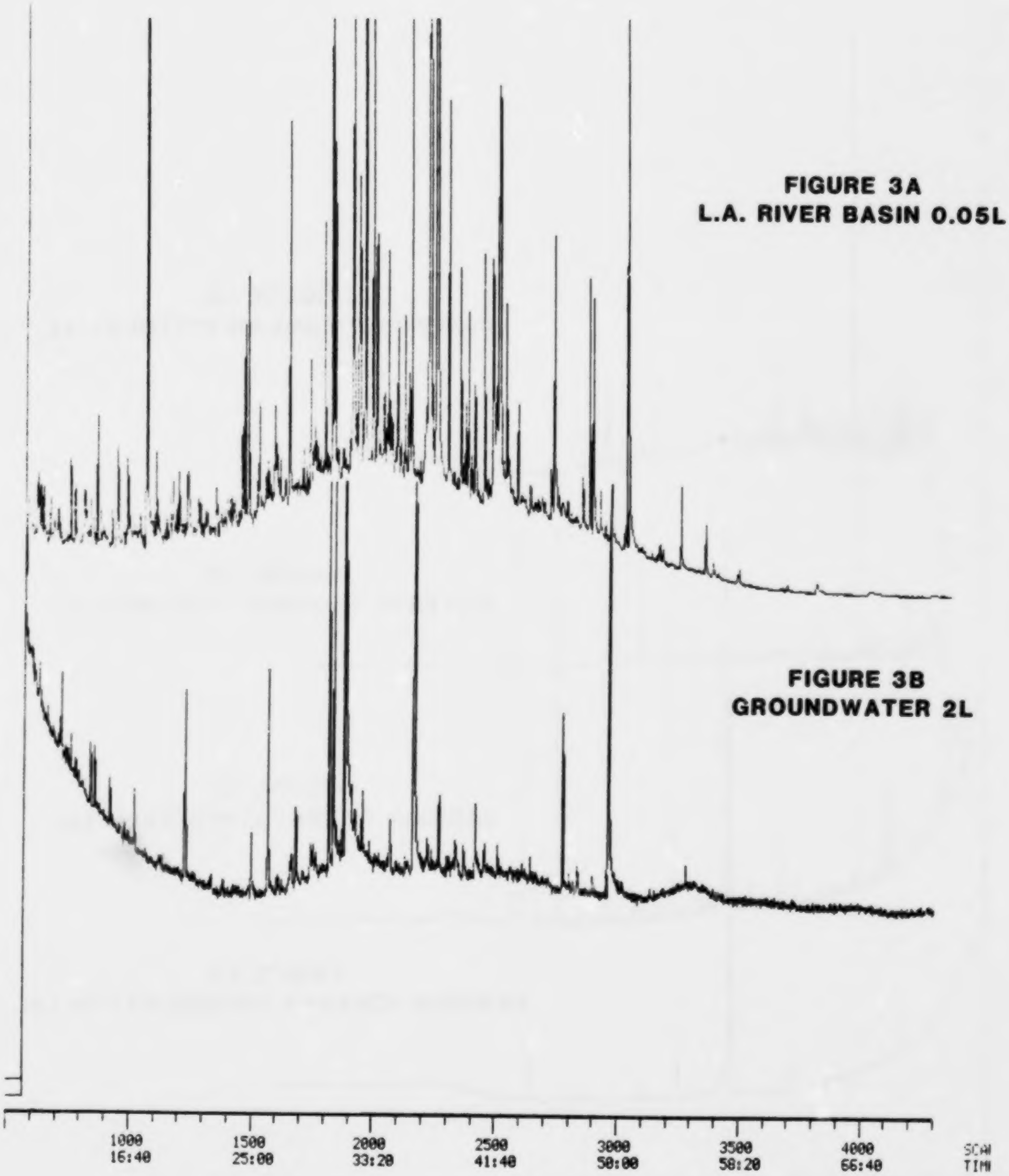


FIGURE 3A
L.A. RIVER BASIN 0.05L

FIGURE 3B
GROUNDWATER 2L

FIGURE IV-3 COMPARISON OF RELATIVE AMOUNTS OF CHROMATOGRAPHABLE ORGANICS IN GROUNDWATER AND SURFACE (dry runoff) WATER IN SAN FERNANDO BASIN

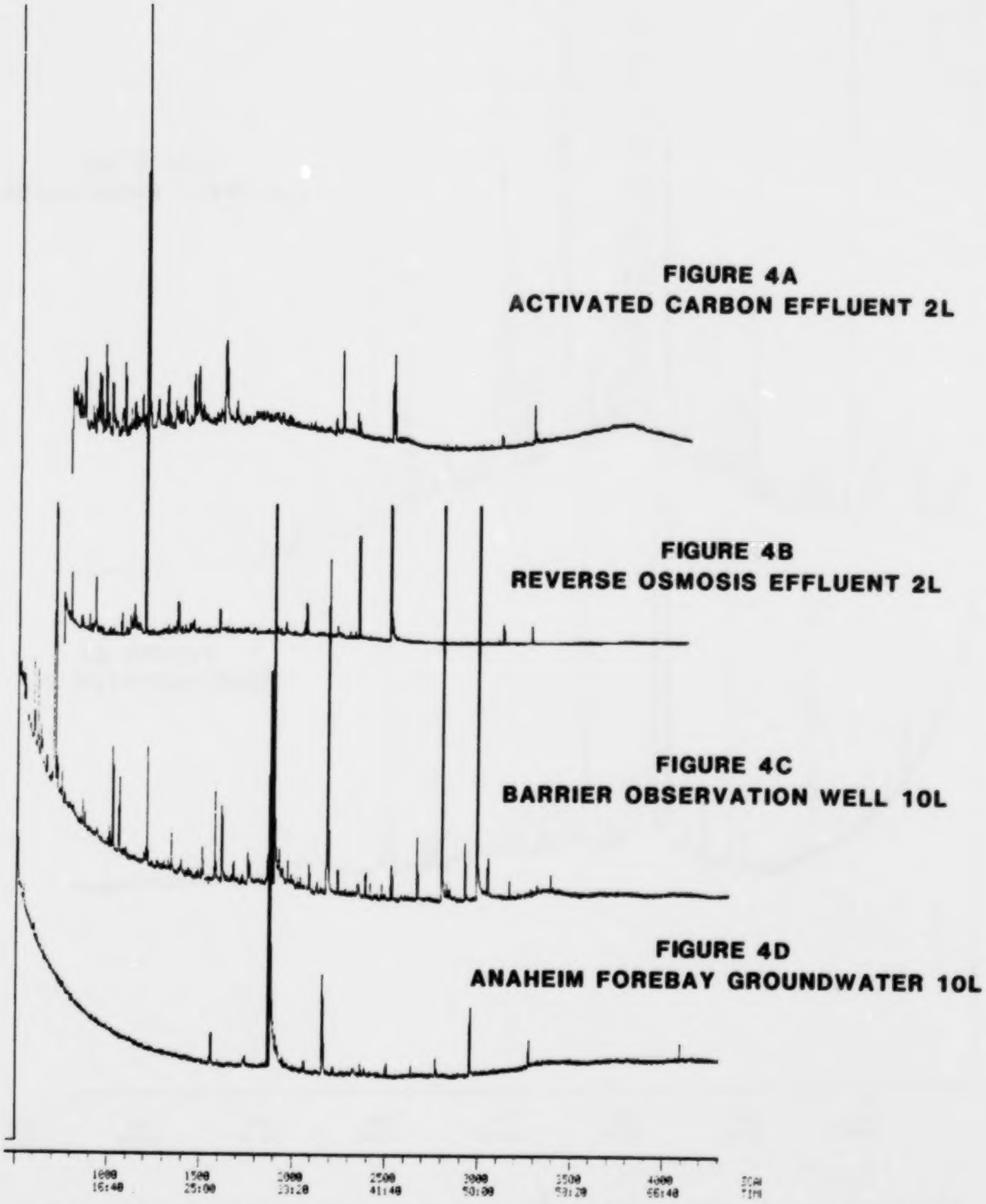


FIGURE IV-4 COMPARISON OF RELATIVE AMOUNTS OF CHROMATOGRAPHABLE ORGANICS IN ORANGE COUNTY SAMPLES

area. In the Orange County area (Figure III-3), it appeared (Figure IV-4) that reclaimed water injection had effected the Talbert Barrier area groundwater when comparing the organic complexity of the observation wells to that of the Anaheim Forebay wells and the Water Factory 21 effluents, although a comparison based on such general measurements could also be influenced by other factors including soil organic content and surface runoff. Both the Talbert Barrier observation wells and Anaheim Forebay wells were generally "cleaner" than either Montebello Forebay or San Fernando Basin groundwaters in terms of general organic content.

Although these comparisons indicate that the relative organic burdens in different water supplies can be estimated by non-specific means, no real information regarding health significance is provided. The temptation exists to assume that the largest gas chromatography components are somehow related to health significance, and the inclination to identify these major components in any given sample is inescapable. The most significant finding resulting from this type of exercise in this study was the general characterization of several miscellaneous groups of compounds in the μg/L concentration range in source waters, and lower in well waters, which comprised the major organic components. These are summarized in Table IV-4. Petroleum byproducts and metabolic byproducts were the predominant materials found, followed by industrially important materials such as plasticizers, hydrocarbon solvents, and detergents. The detection of these in treated wastewaters (IV-17) and rainwater (IV-178) for the Los Angeles area have been reported and discussed elsewhere. These materials in general probably do not present serious chronic health problems at the levels found in drinking water. However, subsequent study efforts attempted to determine possible health impacts corresponding to specific chemical and toxicological characteristics of selected representative compounds from these and other groups of organics, and to assess the relative importance in different sample types. Ensuing sections of this chapter describe the efforts to identify purgeable and non-purgeable organic compounds of known health significance in water (target organics) as well as classes of organics (organohalides and epoxides) contributing to mutagenic activity in many of the samples.

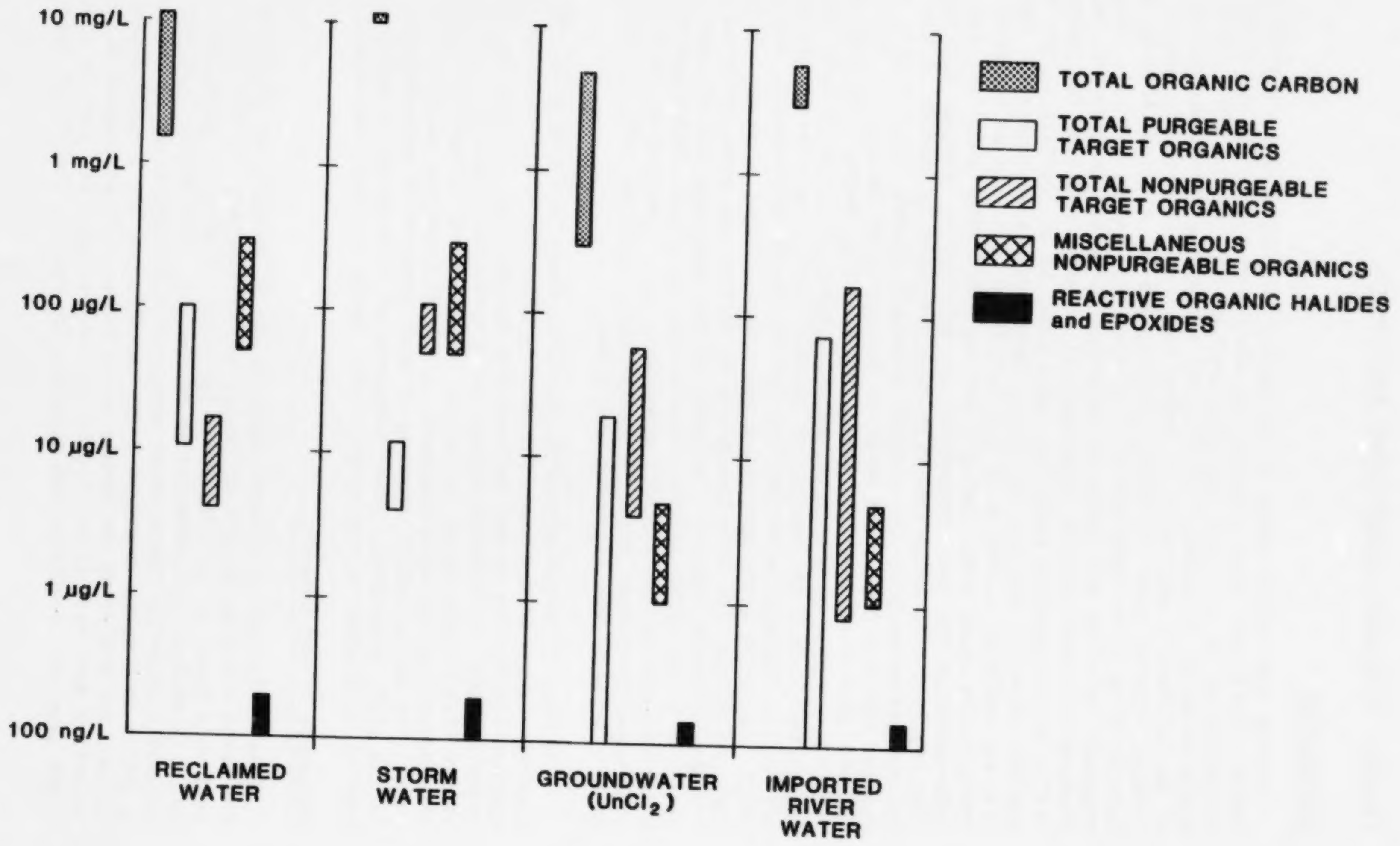
All of this work has led to the identification of a hierarchy of organic types in groundwater and recharge sources. Figure IV-5 compared the approximate levels of target organics, miscellaneous non-purgeable organic compounds, and the reactive aklyl halides and epoxides with the total organic carbon concentrations measured in reclaimed water, storm water, Montebello Forebay groundwater, and imported river water. This graph illustrates that analysis of groups of compounds and individual compounds within these broad categories was required at levels from two to six orders of magnitude below the total mass of organic matter (represented by TOC) and that about 90 percent of this mass remained undifferentiated by chemical analysis in any sample type. This fact is reflective of the limitations of available analytical methods as well as the desire to focus analytical attention on the small fractions of the organic mass which are suspected of containing health significant materials.

TABLE IV-4

MISCELLANEOUS GROUPS OF COMPOUNDS FOUND IN SAMPLE RESIDUES

Compound Type	Sample Types (Predominant)
Petroleum and Combustion Byproducts	
alkyl benzenes	wells, reclaimed, surface
napthalene and alkyl napthalenes	wells, reclaimed
alkyl phenols	wells, reclaimed
alkyl phenanthrenes	wells, reclaimed, surface
ketones	wells, reclaimed, surface
glycol ethers	wells, reclaimed, surface
branched chain aliphatics	wells, reclaimed, surface
aldehydes	wells, imported, reclaimed, surface
Metabolic Byproducts	
fatty acids	wells, imported, reclaimed, surface
aromatic acids	wells, imported, reclaimed, surface
esters	wells, reclaimed
alcohols	wells, reclaimed
Industrial Materials	
phthalates	wells, imported, reclaimed, surface
styrenes	wells, reclaimed
hydrocarbon solvents	wells, reclaimed, surface
detergents	wells, reclaimed, surface

FIGURE IV-5 MEASURABLE ORGANIC MATTER–APPROXIMATE RANGE OF CONCENTRATIONS IN MONTEBELLO FOREBAY GROUNDWATER AND PERCOLATION SOURCES



TARGET ORGANIC COMPOUND ANALYSES

Introduction

During the initial phase of the Health Effects Study, a preliminary list of health significant trace organics was developed for survey purposes. Criteria for selection to this list included presence on: (a) the EPA's list of consent decree priority pollutants (IV-53); (b) proposed effluent monitoring guidelines of the California Department of Health Services (IV-54); (c) Federal Interim Primary Drinking Water Standards (IV-55); and (d) National Academy of Sciences Safe Drinking Water Committee list of toxic substances (IV-11). Many of the compounds selected were known or suspected mammalian carcinogens, while others produced different chronic organ-specific damage. Most of the compounds, especially the halogenated aromatics, were known to be inactive in the Ames test so specific chemical analysis for these compounds was appropriate. The tentative list was modified according to the likelihood that a given compound would be found in the study area's potable and reclaimed water supplies, and whether information on its toxic properties was definitive. Further modification of the list resulted from comparison with data generated by studies of the Los Angeles County Sanitation Districts (LACSD) treatment system, specifically at the Pomona, San Jose Creek, and Whittier Narrows water reclamation facilities. The primary sources of this information included the Pomona Trace Organics Study (IV-19), a report on practicing water reclamation plants by Gulf South Research Institute (IV-56), the results of LACSD's in-house monitoring for the Los Angeles Regional Water Quality Control Board requirements, and on-going LACSD industrial waste monitoring and source control programs. A few compounds remained on the list even though one or more of the above criteria were not met, for the following reasons: (a) some of the compounds had not been subjected to analysis in the LACSD system; (b) previous analytical techniques may have discriminated against specific compounds; (c) a compound may have been a potential human carcinogen found in several water supplies; and (d) non-carcinogenic chronic effects from ingestion were known.

The list of target compounds selected, shown in Table IV-5, represents several classes of man-made, potentially hazardous organics which seemed appropriate for the survey and possibly suitable for tracing the impact of organic matter in recharge sources on groundwater supplies. A large percentage of the list is made up of refractory or persistent halogenated organics; most of the aromatic halogenated compounds on the list are not mutagenic in the Ames test. The toxicological response of each compound is referenced in Table IV-5. As the study progressed, other compounds of interest which appeared in well samples were added to the target list. These are also indicated in Table IV-5.

Purgeable Target Organics

The analytical procedures used for the GC/MS analysis of PTO were based on the purge-and-trap methods of Bellar and Lichtenberg (IV-39). The GC/MS parameters were based on EPA procedures for volatile priority pollutants (IV-63). Detailed methods are presented in Appendix F. The method involved stripping the purgeable organics from a water sample with helium, trapping the volatilized organics on a solid absorbent trap, backflushing the trapped organics onto a GC column, and analyzing the sample using temperature programmed GC/MS and computerized data reduction. Typically, samples were analyzed in sets of six to eight samples. Precision and accuracy for routine analytical operations were

TABLE IV-5

TARGET ORGANICS AND THEIR SUSPECTED HEALTH EFFECTS

Compound	Health Concern Chronic	 Acute	Mutagen	References
vinyl chloride	liver carcinogen	-	+	IV-11
methylene chloride	U [b]	liver damage	+	IV-11
chloroform	carcinogen	liver damage	0	IV-11
bromodichloromethane	carcinogen(?)	liver damage	+	IV-12
dibromochloromethane	carcinogen(?)	liver damage	+	IV-12
bromoform	carcinogen(?)	kidney & liver damage	+	IV-11,12
carbon tetrachloride	liver carcinogen	liver damage	0	IV-11,12
1,1-dichloroethane	U	U	U	IV-57
1,2-dichloroethane	carcinogen, liver damage, leukocytosis	liver & kidney damage, corneal damage	+	IV-11
1,1,2-trichloroethane	carcinogen, liver & kidney damage	GI upset,[c] narcosis, arrythmia	+	IV-11,12
trichloroethylene	carcinogen	liver damage, tachycardia, arrythmia, CNS [d] depression	0	IV-11
tetrachloroethylene	carcinogen	liver damage	0	IV-12
chlorobenzene	liver damage, methemoglobinemia	CNS depression, rbc degeneration	0	IV-11
1,4-dichlorobenzene	liver damage, anemia, cataracts	respiratory problems, tremors	0	IV-11
1,2-dichlorobenzene	liver damage, leukopenia	respiratory problems, tremors	0	IV-11
benzene	leukemia	respiratory failure	0	IV-11
toluene	leukemia(?)	liver damage	0	IV-11
1,2,4-trichlorobenzene	liver damage	-	0	IV-57
phenylacetic acid [e]	teratogen	U	0	IV-11
2,3,5-trichlorophenol	liver & kidney failure	U	U	IV-57
2,4,6-trichlorophenol	carcinogen	U	U	IV-58
2,4,5-trichlorophenol	liver & kidney failure	U	U	IV-58

TABLE IV-5 (Cont.)

TARGET ORGANICS AND THEIR SUSPECTED HEALTH EFFECTS

	Health Concern			
Compound	Chronic	Acute	Mutagen	References
2,3,4-trichlorophenol	liver & kidney failure	U	U	IV-58
2,3,6-trichlorophenol	liver & kidney failure	U	U	IV-58
3,4,5-trichlorophenol	liver & kidney failure	U	U	IV-58
hexachlorobenzene	carcinogen, teratogen	CNS failure	U	IV-11,12
pentachlorophenol	teratogen, liver damage	respiratory failure, kidney failure	U	IV-11
simazine e/	thyroidism	dermatitis	0	IV-11
atrazine e/	thyroidism	dermatitis	0	IV-11
propazine e/	thyroidism	dermatitis	U	IV-11
BHC/Lindane	carcinogen, liver damage	CNS & brain damage, circulatory failure	0	IV-11
2,2',5-trichlorobiphenyl	carcinogen	CNS & liver damage, dermatitis	0	IV-11
2,3',5-trichlorobiphenyl	carcinogen	CNS & liver damage, dermatitis	0	IV-11
2,2',4,4'-tetrachlorobiphenyl	carcinogen	CNS & liver damage, dermatitis	0	IV-11
2,3',4',5-tetrachlorobiphenyl	carcinogen	CNS & liver damage, dermatitis	0	IV-11
2,2',4,5,5'-pentachlorobiphenyl	carcinogen	CNS & liver damage, dermatitis	0	IV-11
2,2',3,3',6,6'-hexachlorobiphenyl	carcinogen	CNS & liver damage, dermatitis	0	IV-11
2,2',4,4',5,5'-hexachlorobiphenyl	carcinogen	CNS & liver damage, dermatitis	0	IV-11
aldrin	carcinogen	brain, kidney, respiratory damage	U	IV-11
endrin	carcinogen	brain, kidney, respiratory damage	U	IV-11

TABLE IV-5 (Cont.)

TARGET ORGANICS AND THEIR SUSPECTED HEALTH EFFECTS

Compound	Health Concern Chronic	 Acute	 Mutagen	 References
dieldrin	carcinogen	brain, kidney, respiratory damage	0	IV-11
o,p'-DDT	carcinogen, CNS & liver damage	cardiac failure	0	IV-11
p,p'-DDT	carcinogen, CNS & liver damage	cardiac failure	0	IV-11
o,p'-DDE	carcinogen	cardiac failure	0	IV-11
p,p'-DDE	carcinogen	cardiac failure	0	IV-11
bis-(2-ethylhexyl)phthalate	teratogen, carcinogen	none	0	IV-59, IV-159
butylbenzylphthalate e/	teratogen(?)	none	0	IV-59
phenanthrene	U(non-mutagenic)	U	0	IV-60,61
fluoranthene	U(non-carcinogenic)	U	+	IV-62
benzo(a)pyrene	carcinogen	U	+	IV-11,57
indeno(1,2,3-c.d.)pyrene	carcinogen	U	+	IV-57
1,12-benzoperylene	carcinogen	U	+	IV-57

a/ + = mutagenic; 0 = non-mutagenic.
b/ U = unknown.
c/ GI = gastrointestinal.
d/ CNS = central nervous system.
e/ Compound added to target list part way through the study.

estimated by preparing and analyzing a duplicate sample and one spiked with a test mixture of the PTOs along with a given set of samples. The reliability data, which were considered satisfactory except for vinyl chloride, are presented and discussed in more detail in Appendix F.

Analytical PTO data for all 90 samples are presented in Appendix G. Results are summarized in Tables IV-6 through IV-8 for Montebello Forebay, San Fernando Basin, Anaheim Forebay and Talbert Gap study areas. In the Montebello Forebay, unchlorinated wells generally had low but detectable amounts of many of the target compounds, most frequently including the industrial solvents methylene chloride, chloroform, trichloroethylene, tetrachloroethylene, and the chlorinated ethanes (Table IV-6). Less frequently, brominated trihalomethanes and chlorinated benzenes were detected. Reclaimed water contained the highest levels of most of these compounds, although Colorado River water exhibited the highest trihalomethane (THM) concentrations, and storm waters appeared to contribute to the input of tetrachloroethylene to the Montebello Forebay. These observations indicate that the impact of spreading various source waters containing refractory halogenated organics can be detected in well waters, and that the potential exists for calculation of the relative effects from the different replenishment sources. Samples from the chlorinated wells in the Montebello Forebay contained quite high concentrations of the brominated THMs. The formation of brominated THMs has been observed in other studies, and has been shown to occur as a result of a reaction between bromide ion in the water with the chlorine dosed to form hypobromite ion, followed by reaction of hypobromite with THM precursors (IV-11, IV-19, IV-39, IV-58, IV-64). The bromide ion concentrations (see Appendix A) coupled with the batch chlorination methods used at these wells are probably responsible for the high levels of brominated THMs found.

Results from PTO analyses of samples in the San Fernando Basin are summarized in Table IV-7, and shown for individual samples in Appendix G.1. With the exception of trichloroethylene (TCE) and tetrachloroethylene (PCE), PTO concentrations in groundwater samples were in the same general range as seen in Montebello Forebay wells. It has been assumed that the presence of these solvents was due to infiltration of improperly disposed industrial wastes rather than incidental atmospheric washdown and surface runoff. Concentrations of purgeable organics in the dry weather runoff samples analyzed in this study (represented by Los Angeles River basin samples) were generally less than detection limits with the exception of methylene chloride, chloroform, and PCE. Although the historic impact on groundwater from percolating dry weather runoff cannot be determined, the levels of PTOs seen in this study indicate that incidental runoff is unlikely to have been the major factor in the well water content of solvents like PCE and TCE. Since the dry weather runoff PTO data in the San Fernando Basin samples were comparable to Rio Hondo River storm runoff PTO data in the Montebello Forebay, and since there is no reclaimed water impact on the two San Fernando Basin well fields, it is probable that the high levels of chlorinated solvents in the wells have resulted from illegal disposal in catchment basins or on vacant land.

The results for the Orange County study areas are presented in Table IV-8. Concentrations of methylene chloride and chloroform in the Talbert Barrier observation wells suggest that there may be an impact from the injection of effluent from Water Factory 21 although contributions from surface runoff cannot

TABLE IV-6

RESULTS OF PURGEABLE TARGET ORGANIC ANALYSES IN THE MONTEBELLO FOREBAY a/

Target Compound	Reclaimed Water b/ µg/L	Storm Water µg/L	Imported Water µg/L	Unchlorinated Well Water µg/L	Chlorinated Well Water µg/L
methylene chloride	4.9-56	0.4-0.8	< 0.2-1.7	< 0.2-8.9	< 0.2-1.8
chloroform	5.8-84	< 0.2-0.6	< 0.2-24	< 0.2-2.6	< 0.1-1.6
bromodichloromethane	< 0.1-2.9	< 0.1-0.2	< 0.1-24	< 0.1-0.8	< 0.1-9.1
dibromochloromethane	< 0.1-2.1	< 0.1-0.2	< 0.1-21	< 0.1-0.2	< 0.1-43
bromoform	< 0.1-4.8	< 0.1-1.6	< 0.2-3.6	< 0.1-0.6	< 0.1-50
carbon tetrachloride	< 0.1-12	< 0.1	< 0.1-0.4	< 0.1	< 0.1
1,1-dichloroethane	< 0.1-1.8	< 0.1	< 0.1	< 0.1-2.6	< 0.1-0.4
1,2-dichloroethane	< 0.2-2.2	< 0.2	< 0.2	< 0.2-0.7	< 0.2
1,1,2-trichloroethane	< 0.2-21	< 0.1-0.2	< 0.1	< 0.1-0.2	< 0.2
trichloroethylene	< 0.1-19.4	< 0.2-0.8	< 0.2	< 0.1-2.3	< 0.1-0.2
tetrachloroethylene	< 0.1-17.4	< 0.4-5.7	< 0.1	< 0.2-1.0	< 0.1-0.5
chlorobenzene	< 0.1-1.0	< 0.1-0.1	< 0.1	< 0.1	< 0.1
1,4-dichlorobenzene	0.2-10.2	< 0.1-1.2	< 0.2-0.2	< 0.2-0.4	< 0.2-0.4
1,2-dichlorobenzene	0.2-6.0	< 0.1-1.3	< 0.1-0.1	< 0.1-0.4	< 0.2-0.6
benzene	< 0.2-2.9	< 0.3	< 0.2	< 0.3-0.9	< 0.2-0.3
toluene	< 0.1-1.3	< 0.2-0.2	< 0.2-0.8	< 0.1-0.4	< 0.1-0.2

a/ Range of values for 57 samples.
b/ Chlorinated dual media filtered effluent.

TABLE IV-7

RESULTS OF PURGEABLE TARGET ORGANIC ANALYSES IN SAN FERNANDO BASIN SAMPLES a/

Target Compound	Chlorinated b/ Reclaimed Water µg/L	Pollock Well Field Unchlorinated µg/L	N.Hollywood Well Field Unchlorinated µg/L	Dry Weather Surface Runoff µg/L
methylene chloride	4.4-18.7	< 1.2-1.5	0.1	0.2-2.4
chloroform	5.1-7.9	0.5-4.1	1.4-3.2	0.2-0.9
bromodichloromethane	3.2-7.6	< 0.1-3.9	0.1-0.4	< 0.1
dibromochloromethane	2.9-6.6	< 0.1-1.2	< 0.1	< 0.1-0.3
bromoform	0.9-3.8	< 0.1-1.9	< 0.1	< 0.1-0.2
carbon tetrachloride	< 0.1-0.6	< 0.2-1.1	< 0.1-0.1	< 0.1
1,1-dichloroethane	< 0.1-0.2	< 0.3-2.3	< 0.1	< 0.1
1,2-dichloroethane	0.2-1.2	< 0.2-1.3	0.2-0.3	< 0.2-0.4
1,1,2-trichloroethane	< 0.2	< 0.2	< 0.2	< 0.1-0.2
trichloroethylene	0.4-1.1	1.6-6.7	0.9-27	< 0.2
tetrachloroethylene	2.5-17	2.4-10.0	0.1-1.7	0.1-0.5
chlorobenzene	< 0.1	< 0.1	< 0.1	< 0.1
1,4-dichlorobenzene	2.4-6.8	< 0.3	< 0.3	< 0.3
1,2-dichlorobenzene	0.9-2.6	< 0.1	< 0.1	< 0.1
benzene	< 0.2	< 0.2-0.3	< 0.2-0.5	< 0.2-0.3
toluene	< 0.1-0.4	< 0.2	< 0.3	< 0.2

a/ Range of values presented for three samples per location.
b/ Chlorinated filtered effluent.

TABLE IV-8

RESULTS OF PURGEABLE ORGANIC ANALYSES IN TALBERT BARRIER/ANAHEIM FOREBAY SAMPLES [a]

Target Compound	Chlorinated Activated Carbon Effluent µg/L	Unchlorinated/ Chlorinated Reverse Osmosis Effluent µg/L	Talbert Barrier Observation Wells (unchlorinated) µg/L	Anaheim Forebay Wells (unchlorinated) µg/L	Anaheim Forebay Wells (chlorinated) µg/L
methylene chloride	0.7-2.1	0.3	0.2-1.2	< 0.2-0.8	< 0.2-6.8
chloroform	9.8->200 [b]	0.5-0.7	0.7-4.9	< 0.2-1.2	0.3-0.9
bromodichloromethane	4.9-108 [b]	0.3-0.6	< 0.1-1.4	< 0.1	1.5-4.2
dibromochloromethane	2.2-61.5 [b]	0.3-0.6	< 0.1-0.7	< 0.1	6.3-21
bromoform	0.9-9.2 [b]	0.1-0.2	< 0.1-0.1	< 0.1	21-33
carbon tetrachloride	0.6-0.7	< 0.1	< 0.1	< 0.1	< 0.1
1,1-dichloroethane	< 0.1-0.2	< 0.1	< 0.1	< 0.1	< 0.1
1,2-dichloroethane	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
1,1,2-trichloroethane	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
trichloroethylene	< 0.2	< 0.2	< 0.2	< 0.2-3.7	< 0.2
tetrachloroethylene	0.6-1.2	0.1-<0.2	< 0.1-0.5	< 0.1-1.6	< 0.1
chlorobenzene	< 0.1-0.6	< 0.1	< 0.1	< 0.1	< 0.1
1,4-dichlorobenzene	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
1,2-dichlorobenzene	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
benzene	< 0.2-0.2	< 0.2	< 0.2	< 0.2	< 0.2
toluene	< 0.2-0.2	0.2-0.4	< 0.2-0.7	< 0.1-0.3	< 0.2-0.3

[a] Range of values for 19 samples.

[b] High end of concentration range reflects one sample which was not dechlorinated at time of sampling, resulting in continued THM formation prior to analysis. Refer to Appendix G for individual sample results.

be ruled out as a potential source of organics. It should be noted, however, that some of the Anaheim Forebay well samples, which are not impacted hydrogeologically by injection, contained significantly higher concentrations of many of the PTOs than did the barrier wells. Whether this is the result of incidental percolation of treated wastewater discharged upstream in the Santa Ana River or industrial contamination cannot be determined. In any event, concentrations of PTOs in unchlorinated Anaheim Forebay groundwaters were generally less than 1.0 μg/L and within the ranges reported for Montebello Forebay wells. As observed with the chlorinated Montebello Forebay wells, the one chlorinated well sampled in the Anaheim Forebay also showed elevated levels of THMs, especially the brominated species.

The fact that trace solvents are refractory and migrate readily in groundwater aquifers (IV-67) suggest that water chlorination and industrial disposal practices require close scrutiny if groundwater impacts associated with these types of organics in urban areas are to be minimized. Indeed, disinfection methods for drinking water and reclaimed water have been the subject of much recent research, with emphasis on pretreatment by chemical coagulation, sand filtration, and granular activated carbon adsorption (IV-19, IV-68-IV-71), or on the use of alternate disinfectants such as chloramines, ozone, and chlorine dioxide (IV-19, IV-72-IV-75) to prevent THM formation. However, illegal or otherwise improper disposal of industrial solvents continues to be a problem in terms of groundwater contamination and resultant implications on human health. Although increased regulation and surveillance cannot insure against all illegal disposal reaching the groundwater, they should not be neglected as necessary tools to minimize contamination.

Throughout the course of the study, attention was directed towards the possible incidence of major components in samples which were not on the PTO list. The industrial solvent 1,1,1-trichloroethane was detected at low levels in several samples, including the Los Angeles/Glendale WRP effluent, dry weather surface runoff, and imported Colorado River water. A byproduct of resin manufacturing (IV-76), 2-ethyl-4-methyl-1,3-dioxolane was tentatively identified in all effluents from the San Jose Creek WRP at μg/L concentrations; sub-μg/L traces of the compound were occasionally detected in Montebello Forebay wells. The compound's identity was tentatively established by spectral comparison, but was not verified because a genuine standard was not available. However, the fact that a resin producer is known to contribute flow to the San Jose Creek WRP, supports the tentative identification. The health significance of 2-ethyl-4-methyl-1,3-dioxolane is unknown at this time.

Non-Purgeable Target Organics

Non-purgeable target organic (NPTO) analyses were conducted by GC/MS methods on portions of residues isolated with the resin concentrator as described in detail in Appendix F. Residue portions equivalent to two percent of each sample were prepared in acetonitrile by evaporation to 20 μL; volumes of 1 μL were injected on a capillary GC column, followed by temperature programmed GC/MS analysis. Computer-aided data reduction was used to quantify any detected target organics, using anthracene d-10 or naphthalene d-8 as an internal standard. Results for individual samples and blanks are included in Appendix G. Tables IV-9 through IV-11 summarize data for only those compounds detected in

TABLE IV-9

CONCENTRATION RANGE OF NON-PURGEABLE TARGET ORGANICS FOUND IN MONTEBELLO FOREBAY SAMPLES a/

Target Compound	Reclaimed Water µg/L	Storm Water µg/L	Imported Water µg/L	Unchlorinated Wells µg/L	Chlorinated Wells µg/L
bis(2-ethylhexyl)phthalate	0.7-13	22-82	0.3-167	0.2-59	0.2-5.7
1,2,4-trichlorobenzene	0.4	b/	b/	b/	b/
2,4,6-trichlorophenol	0.03-0.7	1.9	b/	0.5-1.5	b/
2,4,5-trichlorophenol	0.05-0.9	1.7	b/	b/	b/
2,3,4-trichlorophenol	b/	1.8	b/	b/	b/
2,3,6-trichlorophenol	b/	0.7	b/	b/	b/
3,4,5-trichlorophenol	0.2	6.7	b/	0.7	b/
pentachlorophenol	16	6.8	b/	0.8	b/
lindane	1.0	1.4	b/	b/	b/
2,3',5-trichlorobiphenyl	0.07	b/	b/	b/	b/
2,2',4,4'-tetrachlorobiphenyl	0.08	b/	b/	b/	b/
aldrin	0.6-0.9	b/	b/	b/	b/
phenanthrene	1.7	0.3-0.4	b/	b/	b/
fluoranthene	0.1	3.3	b/	b/	b/
DDT	0.05	b/	0.1	b/	b/
dieldrin	b/	b/	0.4	b/	b/
atrazine c/	b/	1.3-3.9	b/	0.5-0.9	0.9
simazine c/	b/	1.5-6.6	b/	d/	1.7
phenylacetic acid c/	b/	1.1-16	b/	2.1-3.1	d/

a/ Concentration ranges; all non-purgeable target organics not in the table were not detected in samples.

b/ Not detected; see appendix F for detection limits.

c/ These compounds were added to the target list only for sample Nos. 47-90 as a result of detection in Nos. 1-46.

d/ Detected, but not quantified.

TABLE IV-10

CONCENTRATION RANGE OF NON-PURGEABLE TARGET ORGANICS FOUND IN SAN FERNANDO BASIN SAMPLES [a]

Target Compound	Chlorinated Reclaimed Water µg/L	Unchlorinated Wells µg/L	Dry Weather Surface Runoff µg/L
bis-(2-ethylhexyl)phthalate	1.4-19.7	0.6-9.4	4.0-11.5
1,2,4-trichlorobenzene	0.9-3.3	b/	0.4
2,3,5-trichlorophenol	b/	b/	0.4
2,4,6-trichlorophenol	0.6-0.9	b/	0.3
2,4,5-trichlorophenol	0.2	b/	0.6
2,3,4-trichlorophenol	b/	b/	0.4
2,3,6-trichlorophenol	b/	b/	0.4
3,4,5-trichlorophenol	b/	b/	2.7
pentachlorophenol	7.6-13	b/	b/
lindane	0.6	b/	b/
fluoranthene	b/	b/	0.01
atrazine c/	b/	0.6	3.4
simazine c/	b/	1.5	8.5
phenylacetic acid c/	b/	b/	9.2

a/ Concentration ranges; all non-purgeable target organics not listed in this table were not detected in study samples.
b/ Not detected; see Appendix F for detection limits.
c/ These compounds were added to the target list for sample Nos. 47-90 after detection in Nos. 1-46.

TABLE IV-11

CONCENTRATION RANGE OF

NON-PURGEABLE TARGET ORGANICS FOUND IN TALBERT GAP AND ANAHEIM FOREBAY SAMPLES a/

Target Compound	Chlorinated Activated Carbon Effluent µg/L	Chlorinated/ Unchlorinated Reverse Osmosis Effluent µg/L	Unchlorinated Talbert Barrier Observation Wells µg/L	Anaheim Forebay Wells Unchlorinated µg/L	Anaheim Forebay Wells Chlorinated µg/L
bis-(2-ethylhexyl)phthalate	0.4-2.9	0.9-1.2	0.2-16	0.4-3.3	0.3-0.5
1,2,4-trichlorobenzene	b/	b/	b/	b/	0.2
2,4,6-trichlorophenol	b/	b/	b/	b/	0.4
phenanthrene	b/	0.1	0.06	b/	b/
atrazine c/	b/	b/	b/	b/	0.9-1.1
simazine c/	b/	b/	b/	3.2-5.7	5.8-7.9

a/ Concentration ranges; all non-purgeable target organics not listed in this table were not in study samples.
b/ Not detected; see Appendix F for detection limits.
c/ These compounds were added to the target list for sample Nos. 47-90 after detection in Nos. 1-46.

the various samples in the four study areas. Unlike the PTOs, the frequency of detection of NPTOs in these samples was low. The compound most often detected was the plasticizer bis-(2-ethylhexyl)phthalate (DEHP). Although the highest concentrations were usually found in storm and dry weather runoff, levels in other sample sources ranged over several orders of magnitude thus making any speculation on relative groundwater impact difficult.

Another class of compounds which appeared in two of 14 Montebello Forebay reclaimed water samples, two of three San Fernando Basin reclaimed water samples, and three of nine surface runoff samples was the chlorinated phenol group; several trichlorophenol isomers and pentachlorophenol were detected in the various source samples. However, only three of 30 well water samples in the Montebello Forebay and one of 15 well samples in the Anaheim Forebay contained traces of any of these, suggesting that surface source concentrations had little impact on the groundwater.

The s-triazine herbicides, atrazine and simazine, were detected frequently in runoff samples, but never in reclaimed water or the imported waters. Although these were only added to the NPTO list for analyses of samples Nos. 47 through 90, one or both were detected in nearly every well (except the Talbert Barrier observation wells) in all areas at some stage of the study. For certain well samples, the two herbicides were below detection levels of the NPTO analytical routine. However, the fractionation/GC/MS methods described later in this chapter facilitated low-level identification of atrazine, simazine, and the related herbicide propazine.

Another compound added to the NPTO list midway through the study, phenylacetic acid, was also found with some regularity in surface runoff and well waters, but never in reclaimed or imported waters. One implication of these findings is that the application or disposal of surface runoff has a distinct and detectable impact on the less volatile organic residues in groundwater.

Several chlorinated aromatic hydrocarbons (polychlorinated biphenyl isomers, DDT, trichlorobenzene, aldrin, dieldrin, lindane) were sporadically detected at trace levels in various sources. Their incidence appeared to be insignificant in terms of percolation practices. Similarly, the tri- and tetracyclic polyaromatic hydrocarbons (PAH), phenanthrene and fluoranthene, were occasionally quantified in reclaimed waters, runoff, and in one well water sample, but could not be linked to planned groundwater replenishment practices.

Most of the NPTOs detected in this phase of the work are either industrially significant or belong to the herbicide/pesticide class. DEHP is widely used as a plasticizer in plastic manufacture, and appears to be ubiquitous in the environment (IV-77). It does not easily degrade, nor does it seem to pose a significant bioaccumulation problem (IV-78). The polychlorinated biphenyl (PCB) isomers detected in reclaimed water are suggestive of the presence of Aroclor 1242 (IV-79), a commercial PCB mixture used as a dielectric transformer oil and once used as a plasticizer. Routine industrial monitoring programs occasionally detect the PCBs in wastewater, although most of the material entering the sewage system ends up in the advanced primary treatment and solids treatment facilities. In contrast to the phthalates, PCBs are bioaccumulative in food chains (IV-80).

The presence of pesticides in well waters is most likely due to land application and the subsequent infiltration of runoff. The State Water Resources Control Board has catalogued the 100 most commonly used pesticides in each county within the State. Using 1974 as a sample year, the following amounts of detected NPTO pesticides were used in Los Angeles and Orange Counties: dieldrin, 3,753 lbs.; aldrin, 2,980 lbs.; lindane, 1,670 lbs.; atrazine, 18,562 lbs.; simazine, 16,770 lbs. Because of a moratorium on its use, DDT was absent from the 1974 list. In recent years (1978-1981), the Los Angeles County Flood Control District's records indicate that approximately 150 lbs. of atrazine and simazine were applied in the San Gabriel River and Rio Hondo spreading basins for weed control. Since all of the NPTO pesticides and herbicides detected are known to be persistent in soils and sediments, it cannot be determined whether the amounts detected in surface supplies are due to historical or recent applications. However, the consistency of detection of simazine and atrazine in the Montebello Forebay wells seems to have clearly resulted from both percolation of surface runoff and from weed abatement programs in the river basins.

The presence of the chlorinated phenols in reclaimed water and runoff is not as simply explained. Pentachlorophenol is used as a fungicide/wood preservative, and commercial mixtures are normally contaminated with other chlorinated phenols (IV-11). These can leach from treated materials and be transported via aquatic systems, or could result from improper domestic and industrial waste disposal. In addition, chlorinated phenols have been reported in industrial wastes and as products of water chlorination (IV-81). Trichlorophenols are used as fumigants and fungicides, and the 2,4,5-isomer is the precursor of, and a contaminant in, commercial preparations of the herbicide 2,4,5-TP (more than 5,000 lbs. were used in the region in 1974), and a constituent of the PCB transformer oils. The biodegradability of the chlorinated phenols varies (IV-11, IV-82); pentachlorophenol, like DDT and PCB, is persistent and seems to bioaccumulate in lipoid tissues of animals, including humans (IV-83).

Fluoranthene and phenanthrene, the two PAHs occasionally detected, are considered to be products predominantly found in industrial areas (IV-61, IV-62, IV-84). They are combustion by-products and may be components in certain petroleum fractions (e.g., asphalts); hence, their presence in samples may be attributable to atmospheric washdown and surface runoff. They are somewhat biodegradable in soils and do not seem to bioaccumulate (IV-84, IV-85). Neither compound is known to be carcinogenic (IV-61, IV-62).

TOXICOLOGY AND TRACE ORGANICS– THE CHARACTERIZATION OF UNKNOWN COMPOUNDS

Introduction

In contrast to the target organic surveys aimed at detection of known compounds having a variety of chronic effects, the objective of work described in this section was to isolate and identify unknown compounds which may be carcinogens. It is this health aspect which has elicited the most concern regarding the presence of organics in drinking water (IV-86, IV-87) and which has posed the most difficult analytical problems to solve. The implication that a high percentage of the cancer incidence in the United States is the result of various environmental exposures (IV-86) has prompted much research in the development of biological methods for detecting potentially carcinogenic materials in different environmental media. Although animal studies have conventionally been used for definitive determinations of carcinogenicity, they are difficult, lengthy, and costly. Therefore, many researchers have focused on developing relatively short term *in vitro* bioassays for detecting the presence of mutagens and carcinogens using test systems such as cultured strains of bacteria, yeast, and mammalian cells, or *in vivo* assays with special strains of the fruit fly *Drosophila* (IV-88, IV-89). These tests can only be considered to be supplementary to animal tests, or to be effective for screening materials for genotoxic effects prior to animal tests; alone they are not considered proof of carcinogenic activity.

At the outset of the Health Effects Study the best characterized of the screening tests was the *Salmonella* microsome mutagen assay developed by Dr. B. N. Ames (IV-22, IV-40, IV-60, IV-87). It was selected as the main toxicology test for the study for the purpose of detecting sample fractions containing genotoxic organics.

Although the purpose of the "Ames test" is to detect potential cancer causing compounds, the test actually detects chemical mutagenicity - the ability to cause genetically transmissable damage to DNA. With few exceptions, toxicologists consider chemical carcinogens to be mutagens (IV-60) although all mutagens are not necessarily animal carcinogens. In the Ames test the correlation between animal carcinogenicity and mutagenic response has been shown to be 90 percent; conversely, 87 percent of non-carcinogens tested were non-mutagenic (IV-60). The test has been shown to be limited for detection of some chlorinated aromatic carcinogens, a fact that was taken into account when selecting the target organic compounds. Since many carcinogens are known to be activated by mammalian enzymes absent in the *Salmonella* test strains, Ames modified the test to include a mammalian liver microsomal homogenate, S9, enabling the test to detect many mutagens which would otherwise be inactive in the assay (IV-22). The tester strains are sensitive to DNA base-pair substitutions and DNA frameshift mutations which cause the organisms to revert from histidine dependence to histidine independence resulting in growth in the test medium. The assay, then, is considered to be a measure of the presence of *presumptive* carcinogens of these types in a test mixture. The *Salmonella* microsome assay has been demonstrated to be a sensitive method for detection of mutagens in a number of materials, including soot, hair dyes and cosmetics, food and food additives, pesticides, industrial materials, airborne particulates, and water supplies (IV-90-IV-98). The applications and limitations of the Ames test in water supplies was recently reviewed in detail by Loper (IV-99), who reported on the use of *Salmonella* strains TA98 and TA100 (with and without enzyme activation) for detection of mutagens in water concentrates from carbon, resins, reverse osmosis, silica gel, and liquid-liquid extraction systems. Evidence presented in this review supported the presence of many low-level (sub-ppb) mutagens in drinking water, although they probably represent a relatively low percentage of the total number of organics present. The evidence for mutagens in drinking water was shown to be broadly based, and in many instances was supported by the use of other short term tests with microbial and mammalian cell test systems.

The fact that complimentary testing has been recommended (IV-100) using several types of screening assays for individual compounds, made it desirable to use a second assay system to augment interpretation of the complex organic mixtures in water supplies. Preliminary evaluation narrowed the selection to mammalian cell transformation tests. Although these tests are specific for carcinogens (IV-23, IV-89), they are still in early stages of development. Transformation assays have not been used extensively on water concentrates, and have only been compared to the Ames test on a limited basis (IV-40). The desirability of including mammalian cell toxicology in the study, therefore, led to the decision to attempt adaptation of such an assay to water concentrates in order to provide a qualitative comparison with the Ames test on selected sample residues. The mammalian cell transformation assay chosen for this study was developed by Chen and Heidelberger (IV-23), and uses the C3H/10T1/2 mouse fibroblast cell line.

Following exposure to a carcinogen, the C3H/10T1/2 cell line undergoes a transformation from a normally oriented growth pattern with a limited life span to cells demonstrating a hereditary random growth pattern with the ability to grow continuously in culture. The normal cells are not tumorigenic when injected into mice, while the transformed cells are able to induce tumors upon injection. Malignant transformations have been quantitatively demonstrated in dose response assays for polycyclic aromatic hydrocarbons (IV-23, IV-101, IV-102), N-methyl-N-nitro-N-nitrosoguanidine (IV-103), several cancer chemotherapy drugs (IV-104), tobacco smoke concentrate (IV-105), and hair dyes (IV-106). The cell line has also been used to study the action of tumor promoting agents in two-step carcinogenesis (IV-107). Successful application of the transformation assay to environmental mixtures also presents the potential for detecting the action of non-mutagenic tumor promoters in complex organic residues.

Strategy for Toxicity Testing

The fundamental precept of toxicology is that of the dose required to elicit a given biological response; toxicity is a graded response related to progressive changes in dose. The degree of biological impairment caused by a given amount of toxicant, i.e., its potency, is governed by many factors in the test organism. However, compounds that cause genetic damage are believed to exert their mutagenic effects at very low levels, and the quantitative relationship between dose and the number of mutations induced at the molecular level is not known either in humans or in test organisms. Consequently, it is impossible to directly relate mutagenic activity of unknown compounds in a cellular assay to potency or health risk in humans and other animals. While it may be instructive to compare relative mutagenic potencies of different types of samples, an acceptable assessment of health risk ultimately requires identification of the compounds causing the genotoxic response.

The experimental strategy for this phase of the study was aimed at characterization and identification of sample components which were suspected of causing mutagenicity in the Ames test. The study design shown in Figure IV-1 employed an iterative cycle of Ames test/fractionation/mass spectral identification, the purpose of which was to isolate relatively simple molecular mixtures containing mutagens from the bulk of the non-mutagenic residue. The goals of the isolation methods were two-fold: (a) resolve individual components to obtain pure mass spectra, and (b) focus efforts on identifying spectra of compounds which had a greater likelihood of being mutagenic. In the course of the work several separation techniques were employed, including acid/base/neutral (A/B/N) extractions, high performance liquid chromatography (HPLC) on normal-phase, reverse-phase, and size exclusion columns, and chemical derivatization. GC/MS techniques included electron ionization (EI), positive ion chemical ionization (PCI), and negative ion chemical ionization (NCI) following capillary column GC introduction into the MS source. In addition, liquid chromatography/mass spectrometry (LC/MS) was experimented with as an adjunct technique in the EI mode. Ensuing sections of this chapter describe the experiments and results of this work.

Mutagen Testing of Whole Residues

Ames mutagen testing was conducted on ten percent portions of the organic residue for each of the 90 samples collected with the high performance concentrators. The primary purpose of the initial testing was to select those samples which would be subjected to additional evaluation for genotoxic compounds. Details of the bioassay protocol are given in Appendix H. Briefly, the dose-response plate incorporation methods of Ames (IV-108) were used. Acetonitrile residues were reconstituted with sterile dimethylsulfoxide (DMSO) and tested in duplicate at three or four dose levels with Salmonella typhimurium test strains TA98 and TA100, with and without S9 enzyme activation. Two or three different S9 doses were used for each sample dose. Appropriate positive and negative controls were run with each assay as recommended by Ames (IV-108). Net revertants were calculated by subtracting the spontaneous reversion rate of the control from the reversion rate of the sample; a mutagenic (positive) scoring required that a dose-response be exhibited with a reversion rate of at least two times the spontaneous rate. Revertants per liter (Rev/L) were calculated from the average net revertants divided by the volume equivalent of the original sample dosed.

Typically, residues tested were concentrated by a factor of approximately 10^4. Assay sensitivity relative to the sample volume collected and the residue doses used in the test are estimated in Table IV-12. It is apparent from this table that sampling and test protocols play a significant role in the outcome of the Ames test. For this reason, samples Nos. 1-17, with sample volumes of 10 to 20 L, had significantly poorer sensitivities than the samples collected with the high volume concentrator. This concept and an estimation of the precision of the assay are needed to evaluate and compare test results with various sample types. For reference, an estimate of test precision is described in Appendix H for randomly selected sets of positive controls run during the study on TA98 and TA100 with and without S9 enzyme activation.

Examination of results from mutagen assays of whole residues suggested that there were significant differences in sample types. Table IV-13 summarizes the mutagenicity of samples taken from all four study areas, and detailed results are shown in Appendix I. Although significant differences were observed between

TABLE IV-12

SALMONELLA MICROSOME MUTAGEN ASSAY - APPROXIMATE SENSITIVITY RELATIVE TO VOLUME CONCENTRATED AND MAXIMUM RESIDUE DOSE PER PLATE a/

Sample Volume (L)	Residue Dose b/ (μL)	Sample Volume Equivalent (mL)	Revertants/Liter	
			TA98	TA100
10	150	60	500	2670
20	200	100	300	1600
100	200	500	60	320
200	200	1000	30	160

a/ A reversion rate of two times the control reversion rate was considered to be the lowest significant positive dose; a dose dependent response was a second criterion for scoring a positive result.

b/ Ten percent of the concentrator residue dissolved in 4 mL of 1:1 CH_3CN/DMSO solution was used for each assay; the maximum dose of this concentrate/plate was selected to insure against solvent toxicity.

TABLE IV-13

MUTAGENICITY (REVERTANTS/LITER) INDUCED BY ORGANIC RESIDUES FROM VARIOUS WATER SOURCES

	Salmonella Tester Strain			
Sample Type a/,b/	TA98	TA98 + S9	TA100	TA100 + S9
Reclaimed water (N=21, S=5, X=6)	90-4900	50-3300	330-5200	<130-3400
Imported water (N=6, S=2, X=0)	60-190	<30-50	<130-330	<130
Storm runoff (N=6, S=1, X=0)	1300-4000	970-4800	1000-2600	<1300
Dry runoff (N=3, S=1, X=0)	1200-1900	570-840	1800-3000	720-1200
Unchlorinated wells (N=45, S=15, X=7)	30-2800	40-1500	100-1400	<110-540
Chlorinated wells c/ (N=9, S=3, X=1)	50-720	30-400	120-720	100-420

a/ Expressed as a range for N number of samples from S number of sources; X samples out of the total N were negative on both strains and are not included in the table.

b/ Out of 90 samples, 23 were 10 to 20 L, while 67 were 100 to 200 L; 12 of the former were Ames negative, presumably due to the ten-fold higher detection limits. Only two of the large samples (unchlorinated wells) were negative. A complete listing of mutagenicity data and sample source can be found in Appendix I.

c/ One sample from a chlorinated source gave 20,000 Rev/L on TA98; this was judged to be an anomaly and not included in the table, since subsequent assays of other samples from the source were about 100 times lower in potency.

sample types, no significant differences were evident in similar samples from the different study areas. Seventy-six of 90 samples were mutagenic; of the 14 negative samples, 12 were among the first 17 samples taken on the smaller prototype concentrator. Using the high volume concentrator, at least one mutagenic sample was collected from each sampling site. However, even with a dose equivalent to one liter of sample per test plate, several of the groundwaters and some of the source water samples after No. 17 were only marginally active in the test. Based upon the published range of mutagenic potencies of known compounds (see Appendix I, Table I-3), the low activity in these unknown mixtures would suggest that extremely low concentrations of individual mutagens are present in these samples (IV-60).

Storm runoff and dry weather runoff consistently yielded the highest levels of mutagenicity of percolation source waters. State project water and Colorado River water appeared to contribute the least mutagenicity of the sources tested, nearly two orders of magnitude less than storm waters. Reclaimed water concentrates had mutagenic responses spanning the range between imported and surface runoff sources. Reverse osmosis effluent and some secondary effluent samples had activity similar to the imported water samples, whereas responses for other reclaimed water samples ranged as high as the results for the storm runoff samples. The levels of mutagenicity observed on TA98 and TA100 were similar to the range of data reported in the literature for drinking water (IV-40, IV-109, IV-115, IV-176) and reclaimed water (IV-42, IV-175, IV-177) for most samples tested.

Mutagenic response for whole residues almost always occurred without the need for S9 enzyme activation. The addition of S9 usually lowered mutagenicity, suggesting a detoxification of direct acting mutagens. This behavior is a common feature of water residues subjected to Ames testing (IV-99). Mutagenicity sometimes occurred on TA98 only, but most frequently on both tester strains, which suggested the presence of compounds capable of acting both as frame-shift and base-pair substitution mutagens. The compounds known to be direct acting mutagens on both TA98 and TA100 are few (IV-60), and comprise cyclic or heterocyclic alkylating agents having amino, epoxy, or halogen functional groups.

Examination of the activity pattern with the two tester strains for different sample types showed that chlorinated wells were positive on both TA98 and TA100 90 percent of the time, compared to 70 percent for unchlorinated wells. Surface runoff followed this pattern 78 percent of the time compared to 38 percent for reclaimed waters and 16 percent for imported waters. A breakdown of reclaimed water types showed the following incidence on both strains: chlorinated - 44 percent; dechlorinated - 50 percent; unchlorinated - 0 percent. This is the only direct evidence that chlorination of reclaimed and well water samples increased the incidence of mutagenicity, in this case, on strain TA100. The observation is more apparent in reclaimed waters, which had a higher organic content than the wells. The results are also consistent with literature reports that chlorination of water supplies leads to the formation of TA100 mutagens (IV-60, IV-109), ostensibly due to oxidation/halogenation reactions of organic mixtures present in the samples. However, the fact that chlorine residuals in most of the reclaimed waters were chloramines may have prevented a pronounced increase in mutagenic activity such as that observed in the literature. In this study, the effects of dechlorination on mutagenicity were not directly evaluated, although the work of Cheh (IV-109) indicated that partial destruction of mutagens formed during chlorination should occur upon dechlorination with sulfite.

A unique feature of imported river water and storm runoff samples was the relatively high level of TA100 activity which was completely destroyed by addition of S9, and the frequent increase in TA98 mutagenicity with addition of S9. This behavior, contrasted with the partial reduction of TA98 and TA100 activity by S9 in other percolation sources and groundwaters, suggests the presence of several types of mutagens rather than a single compound active on both strains.

Although the small number of sampling events at each sample site precludes rigorous statistical treatment of the mutagenicity data, some additional observations deserve comment. There appeared to be no seasonal effect on mutagenicity in the wells, which was not surprising in view of the complexity of the percolation process and aquifer systems. For the Montebello Forebay wells, there was no simple correlation between percent reclaimed water and the occurrence or level of mutagenicity observed. By inference, this suggests no simple correlation with the amounts of other percolation sources in the groundwater. Although it is possible that there is an association between the mutagenicity in different percolation sources and groundwater, the correlation is probably too complex to be sorted out from bioassay data alone.

Mammalian Cell Transformation Assay of Selected Residues

Initially, it was proposed to evaluate 25 samples by the mammalian cell transformation assay based on Ames test outcome. Assays were contracted for mammalian cell cytotoxicity, transforming ability, carcinogenicity induction in mice, and promoting action. Adaptation of the assay to water residues by the contractor, however, was hindered by a number of problems, the most significant of which was fungal contamination of the USC laboratories. Therefore, only cytotoxicity and the transformation assays on the 25 samples could be completed with the available quantity of sample residue and other resources.

Detailed procedures for these tests are presented in Appendix H. Residue doses in acetonitrile/DMSO were tested in replicate on petri dishes to determine the degree of inhibition of cell growth. Following this determination of toxicity, doses were selected for the transformation assay. Doses were applied to cells for 48 hours, and then removed in favor of fresh nutrient media. The media was changed every four days until the cell line was confluent. Six weeks after treatment, cells were fixed and stained for scoring. Plating efficiency controls were run with each assay and 3-methylcholanthrene (3-MCA) was used as a positive control.

Dose response cytotoxicity was run on the first nine samples (Appendix H). The relatively low toxicity of the residues led to the decision to perform the remaining transformation assays at the highest solvent dose (0.5 percent) allowable in the test media. Toxicity was then determined in terms of plating efficiency at that sample dose. The concentration of residue in the solvent fixed the concentration of the sample dose tested. Table IV-14 compares transformation assay results for the 25 mutagenic and non-mutagenic sample residues with the corresponding Ames test results. In order to express mutagenic or

TABLE IV-14

COMPARISON OF SALMONELLA/MICROSOME MUTAGENICITY AND MAMMALIAN CELL TRANSFORMATION ASSAY RESULTS IN MONTEBELLO FOREBAY SAMPLES

Sample Number	Sample Type a/	Mutagenicity (Rev/L) b/				Transformation c/ (Type II Foci/mL)
		TA98	TA98$_9$	TA100	TA100$_9$	
6	1580J-UnCl$_2$ Well	(-)	(-)	(-)	(-)	0/13.9
8	1566A-UnCl$_2$ Well	(-)	(-)	(-)	(-)	0/14.4
10	2907-Cl$_2$ Well	(-)	(-)	(-)	(-)	0/10.8
17	1621MM-UnCl$_2$ Well	(-)	(-)	(-)	(-)	0/29
18	SJC-DeCl$_2$ 3°	620	(-)	(-)	(-)	(+) 1/72.6
18-F1	SJC-DeCl$_2$ 3°	(-)	(-)	(-)	(-)	0/24.9
18-F2+F3	SJC-DeCl$_2$ 3°	200	20	(-)	(-)	0/25.7
20	SJC-Cl$_2$ 2°	90	(-)	(-)	(-)	0/37.4
21	2958A-Cl$_2$ Well	75	40	120	(-)	0/57.8
22	1591H-UnCl$_2$ Well	155	70	880	420	0/153
23	1620GG-UnCl$_2$ Well	170	55	(-)	140	0/62
28	WN-DeCl$_2$ 3°	1740	1330	4330	1690	0/21
31	Pomona-Cl$_2$ 3°	110	(-)	800	(-)	(+) 2/53
40	Storm Water	2150	2600	(-)	(-)	0/16
41	1562E-UnCl$_2$ Well	170	230	350	100	0/286
42	State Project Water	170	50	(-)	(-)	0/74.2
43	Colorado River Water	115	70	(-)	150	(+) 3/87
44	1514A-UnCl$_2$ Well	170	115	295	(-)	(+) 1/211
45	1621MM-UnCl$_2$ Well	360	225	405	(-)	0/39.1
46	1620GG-UnCl$_2$ Well	1000	(-)	(-)	(-)	0/230
47	1562E-UnCl$_2$ Well	30	(-)	(-)	(-)	0/104
48	2947Q-UnCl$_2$ Well	135	65	(-)	(-)	0/146
49	1580J-UnCl$_2$ Well	355	(-)	(-)	(-)	0/26.8
50	1566A-UnCl$_2$ Well	150	(-)	365	(-)	0/141
51	2907-Cl$_2$ Well	110	(-)	305	(-)	0/140

a/ UnCl$_2$ = unchlorinated; Cl$_2$ = chlorinated; DeCl$_2$ = dechlorinated; SJC = San Jose Creek WRP, WN = Whittier Narrows WRP; 2° = secondary effluent; 3° = tertiary effluent; F = fraction number.

b/ (-) = non mutagenic.

c/ (+) = positive transformation.

transformation events as whole numbers, units of volume are different for the two assays. For the strongly (Ames) mutagenic samples, it seems apparent from the table that the transformation assay either lacks sensitivity at the dose tested (samples were not tested at high enough cytotoxic levels) or that the Ames mutagens are not carcinogenic in the mouse cell line. The situation was compounded by testing at too low of a dose for the weakly mutagenic samples even though some loss of plating efficiency was suggestive of cytotoxicity. Table IV-15 compares the approximate amount of organic carbon tested in the two assays. It can be seen that the maximum amount tested in the transformation assay was usually at the low end of the dose range used in the Ames test, a fact that may be partly or entirely responsible for the test outcome. Only four sample residues (Nos. 18, 31, 43, 44) showed any transformations, and there was little in common between them in the way of Ames response except that they were all mutagenic on TA98 without S9. The transformations were scored as Type II foci, which induce in vivo carcinogenesis 50 percent of the time when injected into syngenetic mice (IV-110). Type III foci were not detected (80 percent induction rate) in any sample residues. These few transformations are insufficient to establish that any sample contained carcinogens. The transformation in those four samples do support the results of the Ames test, indicating the presence of low levels of genotoxic materials in these samples. The presence of direct acting mutagens (shown by the Ames test results on 20 of 25 samples in this experiment), is not contradictory to the negligible cell transforming activity observed since direct-acting alkylating carcinogens with a short half-life in the test media are not expected to produce morphologic transformations under the conditions of the assay (IV-111).

It is felt at this time that the value of a mammalian cell transformation assay of complex organic mixtures has not been demonstrated. However, since the utility of a cell transformation assay for the detection of carcinogens and promoting agents is potentially great, efforts should be continued in development of a cell line and protocol for use as an adjunct screening procedure for organic residues. Improvement in relative sensitivity by testing higher residue concentrations, and an increased sample throughput rate should be useful. At this time, adequate protocol testing for cytotoxicity, mutagenicity, carcinogenicity, promotion, and induction requires in excess of 400 mg of residue if appropriate sensitivity is to be achieved in a cell transformation test. Use of the entire battery of assays on various fractions of interest requires proportionately more residue. Therefore, for drinking water, concentrates from 500 to 2000 L sample volumes would be required for full utilization of the existing procedures with the 10T1/2 cell line.

With regard to multiple- or tier-testing schemes using multiple in vitro assays, quantitative cross-referencing with positive and negative controls between several candidate screening assays is recommended before appropriate methods can be determined for a particular application. This in turn implies that several types of screening assays need to be adapted to testing of water residues before such comprehensive assays can be performed.

TABLE IV-15

COMPARISON OF TOC DOSES FOR AMES AND MAMMALIAN CELL TRANSFORMATION TESTS

Sample [a] Number	TOC Dose Range μg/Ames Plate	TOC Concentration μg/mL on Ames Plate [b]	TOC Dose μg/MCT Plate [c]	TOC Concentration on MCT Plate μg/mL [c]
6	0.96-145	0.37-53	10	2.5
8	0.4-56	0.15-20	4	1.0
10	1.7-127	0.65-46	7	1.8
17	0.85-64	0.33-23	10	2.5
18	30-3010	12-1115	60	15
18-F1	125-1670	48-596	40	10
18-F2+F3	225-3000	87-1070	81	20
20	660-6580	254-2350	252	63
21	190-760	73-270	25	6
22	215-860	83-310	73	18
23	74-740	28-260	81	20
28	425-4240	163-1515	203	51
31	230-2320	88-830	66-132	16-33
40	175-1750	67-625	140	35
41	265-1060	102-380	153	38
42	1575-6300	605-2250	234	58
43	300-2980	115-1065	133	33
44	150-600	58-215	67	17
45	58-580	22-205	13	3
46	86-860	33-305	81-102	20-26
47	54-540	21-195	40	10
48	23-225	8.8-80	20	5
49	515-2055	198-735	199	50
50	115-467	44-170	40	10
51	325-1300	125-465	98	25

[a] For reference to sample numbers see Appendix I; F = fraction number.

[b] (Volume overlay media + volume cell suspension + volume buffer or enzyme mix + sample dose volume) divided into μg TOC per dose; volumes are 2.6 to 2.8 mL in overlay.

[c] MCT = mammalian cell transformation.

Fractionation-Mutagenicity-GC/MS Characterizations

In recent years researchers have recognized that organic residues collected from environmental samples were too complex for complete identification of components, even with the use of high resolution capillary GC and high resolution mass spectrometry (IV-17, IV-112). To overcome this problem, several researchers have used a variety of fractionation schemes in different applications for molecular simplification prior to capillary GC/MS. These have included column chromatography (IV-17), extraction with different polarity solvents (IV-112), HPLC (IV-113), and gel permeation chromatography (IV-114). More recently, the power of HPLC has been recognized when used in conjunction with toxicity testing of environmental residues (IV-43, IV-115, IV-116).

This section describes results obtained from experiments designed to simplify complex sample residues by fractionation, followed by mutagen testing of the fractions and GC/MS analysis of mutagenic fractions. The fractionation/bioassay cycle was iterated for a number of samples in order to produce increasingly simpler mutagenic fractions for attempted identification of the chemical mutagens by GC/MS. Physical fractionation methods involved reversed-phase, normal phase, and size-exclusion HPLC, and acid/base/neutral (A/B/N) extractions of sample residues. General analytical parameters for these methods are given in detail in Appendix E. Most of the HPLC work was done with preparative scale reverse-phase (ODS-2) columns using either step- or linear-programmed solvent gradients with acetonitrile (CH_3CN) and water. From three to 72 fractions per sample were collected for mutagen testing using these methods. Other HPLC work included experiments with size exclusion chromatography (SEC) in order to determine molecular weight ranges of mutagens, and with preparative scale normal phase separations used to determine if these would be more efficient than the reversed-phase methods.

Mutagenic fractions were evaluated by GC/MS, normally in the EI mode. Detailed instrument parameters and techniques are described in Appendix F. Temperature-programmed GC separations were performed using 0.25 mm x 30 m fused silica SE54 columns. The flexible column was threaded through the GC/MS interface into the MS analyzer. All data acquisition was computer controlled. The mass spectrometer was tuned and calibrated according to EPA specifications (IV-63). Individual components in each fraction were compared with the 25,000 compound computer-based National Bureau of Standards (NBS) library using algorithms previously described (IV-117). In addition, comparison to literature spectra and manual interpretation were attempted for selected components. The identifications obtained by these means were verified in several instances by GC/MS analysis of genuine standards.

Reversed-Phase Separations, Mutagen Testing and GC/MS Analysis. Thirty-three sample residues (between sample Nos. 18-61) were separated into three or four fractions of different polarity using step gradient solvent programming on a reversed-phase HPLC column. Each fraction was assayed for mutagenicity, along with a portion of the respective whole residue, using the plate incorporation methods described earlier in this chapter. These results are displayed graphically in Appendix I. For most samples, the repeated assays for whole residues showed good agreement with the original results discussed previously and shown in Appendix I. In no instance was the net outcome of the test changed. Although there were some significant changes in potency with a few samples, particularly with S9 addition, the general repeatability suggested that storage of residues in acetonitrile at -20°C for six to 12 months did not have an adverse impact on mutagen response. Another feature of these results was that, with few exceptions, mutagenicity occurred in the least polar fractions (most hydrophobic) of each sample, although the fractionation process often entirely destroyed weak TA100 activity. With the exception of two samples (dry weather runoff and Pollock well field, Nos. 37 and 38), no mutagenicity was observed in the most polar fractions. In a few instances fractionation increased the level of direct acting mutagenicity (TA98) possibly due to separation of cytotoxic material from the mutagenic fractions. In most experiments, the sum of TA98 mutagenicity in sample fractions was similar in magnitude to that observed in the whole sample; no evidence of synergistic effects was seen in these assays. Considerable variability was observed in repeat experiments using S9. This result may reflect the variability in commercial lots of the enzyme mix or the sensitivity of some S9-requiring mutagens.

The results of the step-gradient fractionation/mutagen assay are consistent with the presence of several hydrophobic, direct acting mutagens. However, EI-GC/MS analysis of mutagenic fractions yielded few known Ames mutagens using the NBS library (a list of known mutagens and carcinogens determined to be present in the NBS library is presented in Appendix J for reference). The four compounds which were identified in samples are listed in Table IV-16 with their specific activity in the Ames test. As can be seen, these compounds contributed little to the observed mutagenicity of their respective samples. For comparative purposes, Table I-3 in Appendix I can be consulted for an example of the range of specific activity of known mutagens, and the concentrations of those that would be required in a sample to produce different revertant/liter values.

Two of the mutagens, fluoranthene and benzo(a)pyrene, belong to the PAH class, and as discussed in the NPTO section, are combustion by-products. Benzo(a)pyrene, besides being a mutagen, is an animal carcinogen (IV-61). Although it is on the NPTO list, it was not detected in these samples using the NPTO analytical protocol because of its low level (concentration factors for GC/MS analyses of the fractions were usually 20 to 100 fold greater than for NPTO analysis). Fluoranthene was detected in the two runoff samples and one reclaimed water sample. Although it is not carcinogenic (IV-61), it is reported to be mutagenic in the Ames test (IV-117).

N-nitrosomorpholine and N-nitrosopiperidine, the other two mutagens isolated, are also considered to be potent animal carcinogens (IV-119). Although their origin in the wells is not known, it has been reported that N-nitrosomorpholine is a by-product of tanning, and tire and upholstery manufacture (IV-120); N-nitrosopiperidine is present in food (IV-121), and may result from bacterial nitrosation of piperidine in soil (IV-118). Another of the N-nitroso compounds, N-nitroso-N-methylethylamine, was also tentatively identified in sample No. 41. It is an animal liver carcinogen (IV-119) and is suspected as an Ames mutagen because of its structure. However, since its concentration was similar to the other two N-nitrosamines, it is unlikely that it contributed to the observed mutagenicity. It is not known whether this compound is also an industrial pollutant or if it was formed by nitrate-reducing bacteria in a biological system (IV-118).

TABLE IV-16

KNOWN MUTAGENS IDENTIFIED IN STUDY SAMPLES AND CALCULATED CONTRIBUTION TO MUTAGENICITY

Compound	Sample Number [a/]	Approximate Concentration Range, ng/L	Specific Activity [b/] Rev/ng	Sample Fraction Mutagenicity (Rev/L)	Compound Contribution to Mutagenicity, Range (Rev/L)
Benzo(a)pyrene	41,61	1-10	$4X10^{-1}$	150,360	0.1-1
N-nitrosomorpholine	34,41	10-100	$5X10^{-4}$	150,150	0.001-0.01
N-nitrosopiperidine	41	90-900	$9X10^{-4}$	150	0.1-1
Fluoranthene	20,37,40	10-3300	$2X10^{-2}$	90,2290,1230	0.1-100

a/ For sample listing see Appendix I.
b/ References IV-60, IV-118.

Several unknown compounds were detected in many of the mutagenic fractions at relatively high concentration (µg/L), and may have contributed to the genotoxic activity in some samples. A list of these components is presented in Table IV-17 along with pertinent mass spectral information. Attempts to elucidate structures from EI, PCI, and NCI mass spectra failed, as did attempts to match the spectra with those in published compendia (IV-121-IV-124). Although contribution of these compounds to sample mutagenicity cannot be ruled out, it is not possible for them to have caused the mutagenicity in all of the samples since their frequency of occurrence, distribution in fractions, and concentrations were not consistent with the observed bioassay results.

Many other compounds were tentatively identified in mutagenic fractions which were either:

(a) suspected Ames mutagens due to structure,
(b) not Ames mutagens but mutagenic or carcinogenic in other bioassays,
or (c) stable, toxic materials of specific interest.

The most commonly detected or otherwise interesting of these are listed in Table IV-18. As discussed in the NPTO section, the *s*-triazine herbicides are widely used in the region, including weed abatement programs around the Montebello Forebay. Diphenamide was used in the San Fernando Basin, but not in the Montebello Forebay, and most likely got there from surface runoff. DDT usage was discussed earlier in the chapter. The pesticide intermediate, chlorophenyl isocyanate, was tentatively identified in a Montebello well sample, and is of unknown chronic health significance although it is listed as a highly toxic lachrymator (IV-125). The Los Angeles County Flood Control District provided an additional list of pesticides used during the 1970s, which included the following compounds: methoprene, chlorpyrifos, temephos, fenthion, parathion, and malathion. Of these pesticides, only spectra for the latter two were in the NBS library, raising the possibility that the others could comprise some of the unknown mass spectral components. A literature search led to compilation of a comprehensive mass spectral data base for these, and other commonly used pesticides, as well as their known metabolites. Although none of the major unknowns were on this library list and it has not yet led to identification of any of the unknowns, the list has been included in Appendix K for additional reference. It may be inferred that use of these pesticides has not had an adverse impact on groundwater quality in the study area.

Of the plasticizers listed in Table IV-18, phthalates are non-mutagenic in the Ames test, but are of special interest because of their apparent environmental ubiquity (IV-77) and their suspected action as animal teratogens (IV-59) and animal carcinogens (IV-159). Tributylphosphate, found in several groundwater samples, may be a weak alkylating agent if it mimics the carcinogenic behavior of its analog, trimethylphosphate (IV-125). However, tributylphosphate was tested and found to be non-mutagenic in the Ames test during this study (see Appendix I). Benzothiazole and 2,5-di-*tert*-butylquinone are used in rubber manufacturing (IV-125), and although their genotoxicity or other chronic toxicity are unknown at the levels detected, compounds in these classes are given acute toxicity ratings at greater concentrations (IV-127).

Of the miscellaneous compounds in Table IV-18, phenylacetic acid was found in wells and surface runoff as discussed in the NPTO section. The chloro-

TABLE IV-17

CHARACTERISTICS OF MAJOR UNKNOWN COMPONENTS FOUND IN MUTAGENIC SAMPLE FRACTIONS

SCAN NUMBER	EI BASE m/z	OTHER EI m/z	PCI m/z	NCI m/z	NUMBER OF SAMPLES	SAMPLE TYPE	FOUND IN BLANKS
1461	117	211,213, 247,249	71,133	79,81 116	2	chlorinated wells	no
2161	188	80,160 216	217	216	33	all	no
2211	221	155,157, 184,223	none	none	3	wells	no
2224	258	260	71,322	79,81 329,331	2	chlorinated wells	no
2377	265	267,184, 186,132, 134	none	none	5	wells	no
2757	129	112,147, 55,57	129,147	none	12	wells	no

a/ Underlined numbers signify major ions.

TABLE IV-18

POTENTIALLY TOXIC SUBSTANCES IDENTIFIED IN MUTAGENIC RESIDUES

CLASS/Compound	Relative a/ Retention Time	NBS Fit b/	NBS Purity	Number of Samples Detected	Sample Type c/	Concentration Range d/ (μg/L)	Toxicity e/
PESTICIDES							
atrazine f/	2.487	988	863	20	W,S,D	0.1-10	M
simazine f/	2.460	995	842	10	W,S,D	0.1-10	M
propazine f/	2.508	761	841	2	W	<1	M
diphenamide f/ (N,N-dimethyl-2,2'-diphenylacetamide)	3.131	988	946	8	W	0.1-4	OS
DDT f/	3.552	867	782	2	W	t	C
chlorophenylisocyanate	0.933	954	839	1	W	0.05	OS
PLASTICIZERS							
butylbenzylphthalate f/	3.699	974	800	22	W,S,D,R	0.2-120	T
dibutylphthalate f/	3.001	958	985	16	W,S,R	0.1-100	T
diethylphthalate f/	2.166	970	960	5	W,R	<10	T
phthalic acid	1.410	970	947	4	W,R	<10	T
tributylphosphate f/	2.309	978	937	8	W	t-0.1	C?
benzothiazole	1.152	982	925	5	W	t	OS?
2,5,-di-tert-butylquinone	1.818	961	791	8	W	t-5	?
bis-(2-ethylhexyl)phthalate f/	4.037	997	905	87	W,S,D,R	0.3-167	T,C
MISCELLANEOUS							
phenylacetic acid f/	1.219	967	892	10	W,S,D	1-20	T
2-methyl-2H-benzotriazole	1.068	930	897	2	W	t	OS?
1-chloro-2-methylbenzene	0.606	969	890	3	W	0.7-30	OS?
4-bromostilbene(cis/trans), or	2.834	961	791	3	W	t-5	M?
trichlorobiphenyl(isomer)	2.973	954	839				C?

a/ Retention time relative to napthalene d8, 12.01 min.
b/ NBS fit determined by INCOS matching algorithm, 8 peak index; also matched visually with authentic spectrum.
c/ W = well water; S = storm runoff; D = dry weather runoff; R = reclaimed water.
d/ Approximate concentration range except where confirmed by standard; t = trace.
e/ M = mutagenic; OS = organ specific toxicity; C = carcinogenic; T = teratogenic; ? = unknown toxicity, but structurally analogous to known toxics.
f/ Retention time and identification verified with authentic standard.

methylbenzene isomer was found in three samples from the Talbert Barrier observation wells, while the triazole and halogenated polyaromatic were both found in Montebello Forebay wells. The limited occurrence of these compounds precludes speculation on their origins, and presumption of possible health effects is by analogy to similar compounds as referenced in the table. However, at the low rate of incidence, the health significance is doubtful.

Size Exclusion Chromatography/Ames Assay. The inability to identify as mutagens any of the major components in step gradient fractions made it desirable to estimate the molecular weight range of mutagenic materials. Even though it was expected that mutagens should be relatively small molecules (hence gas chromatographable) able to pass through tissue cell walls, the possibility existed that exogenous enzyme activity in the Ames test medium could fragment natural macromolecular material, thus producing mutagenic substances not detectable by GC or GC/MS analysis. Therefore, an attempt was made to assess the involvement of high molecular weight material in mutagenesis. Rough molecular weight fractionation of three mutagenic well water residues was performed by high performance size exclusion chromatography (SEC), followed by mutagen assay of each fraction. Molecular weight discrimination below the 500 to 800 dalton range was not possible with this method, but it was demonstrated that mutagenicity was caused by sample components with molecular weights below this range rather than above. Mutagenic activity in these fractions was similar to the corresponding reverse-phase fraction activity.

Acid/Base/Neutral Partitioning of Mutagenicity. Although the SEC experiments suggested that the mutagens were of low enough molecular weight to be analyzed by GC/MS, it could not be firmly established that they were also amenable to gas chromatographic separation; ionizable, polar materials such as organic acids and bases frequently have poor separability characteristics by GC, and some compounds are heat sensitive to GC/MS conditions. Sealed tube heating experiments with mutagenic residues suggested that heat lability could not account for the inability to detect mutagens by GC/MS (i.e., the compounds did not decompose at injection port temperatures), so the question of ionic mutagens remained to be addressed. Furthermore, it was clear at this stage of the study that eventual identification of mutagens would likely require analyses tailored to specific organic chemical classes, hence it was desirable to further classify the organics in some biologically active fractions.

Residues from two well waters and one reclaimed water were subjected to sequential extraction under acid, base and neutral conditions, and the resulting fractions were assayed for mutagenicity. Results of these experiments showed that most of the mutagens were in neutral fractions, although significant mutagenicity was also detected in acid and base fractions. Further partitioning of the neutrals into polar and nonpolar fractions by solvent extraction (acetonitrile, hexane) yielded different mutagenic ratios for different samples, suggesting some molecular differences in mutagens present in various sources.

Liquid Chromatography/Mass Spectrometry. The use of HPLC interfaced to a mass spectrometer (LC/MS) has been reported as a useful tool for analysis of molecules which are not amenable to GC/MS analysis due to poor volatility, poor thermal stability, or high polarity (IV-128-IV-131). In these examples, greatest utility was realized when analytical methodology was tailored to analysis of specific compounds of interest rather than to unknowns in complex mixtures.

Several mutagenic fractions were analyzed in the study by interfacing the HPLC to the MS using the Finnigan moving belt LC/MS interface. Analytical conditions were as described in Appendix F, using reverse phase gradients (CH_3CN and H_2O) similar to the ones used for residue fractionation (Appendix E). Under these conditions, analytical sensitivity was inadequate for detection of new compounds, with phthalates dominating the chromatograms. This technique was therefore abandoned as a survey method for unknown organics.

Linear Gradient Reversed-Phase Fractionations. Using a linear gradient (CH_3CN/H_2O) on a reversed-phase HPLC column, two unchlorinated well water residues, one reclaimed water residue, and part of the latter separated into acid, base and neutral portions, were each fractionated into 72 parts and Ames tested on TA98. Mutagenicity was undetectable in any of the well water fractions (<20 Rev/L), although the total residues and recombined fractions had activities of 200 and 170 Rev/L, respectively. Similarly the fractions from the acid and base extracts of the reclaimed water sample did not yield detectable mutagenicity. The total and neutral residues from the reclaimed water, originally 4900 and 2000 Rev/L, gave the series of mutagenic fractions shown in Table IV-19. The neutral compounds appeared to contribute about one-half the level of mutagenicity in the total residue, with a similar amount of activity distributed among the positive fractions. The summed activities for total and neutral fractions were somewhat greater than for the intact residue, consistent with the concept of lower toxicity at lower dose discussed earlier in the chapter.

The distribution of activity over many fractions and the partitioning of some activity by acid and base extraction provide additional evidence for the presence of several mutagens representing distinct compound classes. These results as well as those described earlier for step-gradient fractions are consistent with additive rather than synergistic mutagenesis. Unfortunately, EI-GC/MS analysis of the mutagenic subfractions generated by this experiment failed to reveal the identity of any new mutagens or suspected mutagens, even though there was reasonable evidence that, at the least, the neutral mutagens should be thermally stable enough to be analyzed by GC/MS if individual components were present at high enough concentrations to be within the detection limits of EI-GC/MS. The analytical dilemma presented by this set of circumstances is best illustrated by examining an EI mass chromatogram of a mutagenic fraction. Figure IV-6 represents the GC/MS analysis of a mutagenic fraction isolated from a well water (sample No. 41) containing three known mutagens, several non-mutagenic compounds and several unidentified components "buried" in the background signal. Since the sum of contributions from the known mutagens is less than one percent of the observed mutagenicity in this sample (and much less in those samples having no detectable known mutagens), the possibility emerged that the residues contained a multitude of potent mutagens at low individual concentrations below EI-GC/MS detection limits, but which additively contributed to mutagenicity in the Ames assay. Development of analytical methodology to approach this problem required qualitative chemical classification beyond the simple concept of acid/base/neutral extractability.

TABLE IV-19

TA98 MUTAGENICITY OF POSITIVE FRACTIONS FROM LINEAR GRADIENT REVERSE-PHASE SEPARATION OF TOTAL AND NEUTRAL PORTIONS OF A RECLAIMED WATER a/,b/

Fraction Number		Total Residue Rev/L		Neutral Portion Rev/L
34		260		-
40		220		-
43		340		-
44		250		-
47		300		-
48		240		230
49		800		650
50		470		220
51		340		-
52		340		250
53		500		230
54		470		530
55		390		260
56		230		260
57		930		590
58		260		-
	TOTAL	6340	TOTAL	3220

a/ Detection limit = 190 Rev/L.

b/ Linear gradient, 20% CH_3CN/80% H_2O (v/v) to 100% CH_3CN over 30 min; Whatman 10 µm ODS-2 M9, 9.4 mm x 25 cm, 4 mL/min; 2 mL fractions.

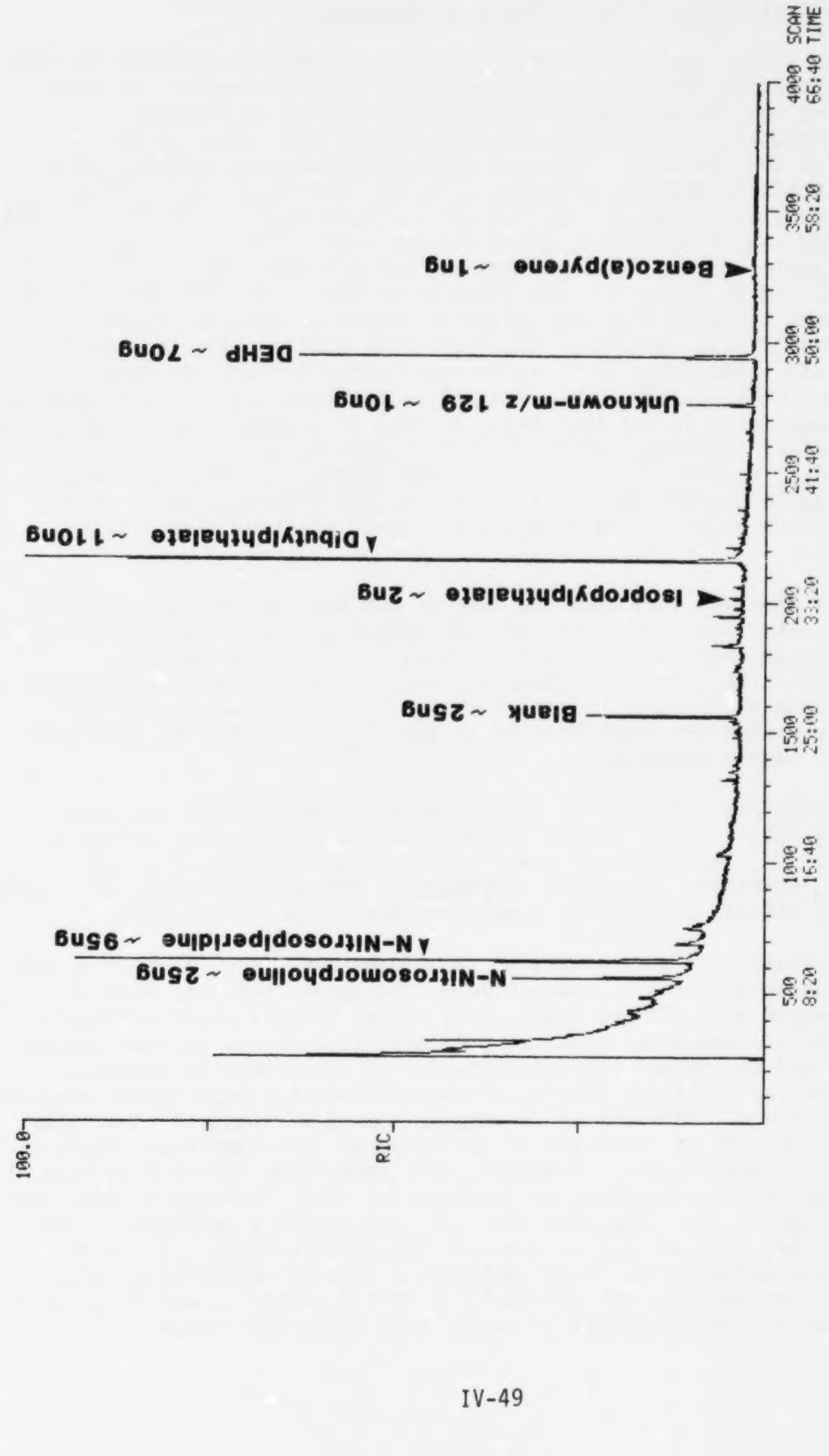


FIGURE IV-6 MAJOR GC/MS COMPONENTS IN MUTAGENIC FRACTION OF A WELL WATER RESIDUE

Chemical Derivatization-NCI GC/MS Analysis of Mutagens

Early in the study, experiments with normal phase HPLC separations of residue fractions indicated that mutagenic activity of several samples was completely lost when the residues were isolated and refluxed in the weak nucleophile 2-propanol. Since direct-acting mutagens are likely to be electrophiles (IV-109, IV-131), reactions with different nucleophiles can be utilized to selectively destroy mutagenic activity contributed by different kinds of electrophiles. Cheh and Carlson (IV-133) and Agarwal, et al. (IV-134) have demonstrated the efficiency of using the nucleophile 4-nitrothiophenol (NTP) to form stable adducts with epoxides and alkylhalides, two potent mutagen classes. Furthermore, NTP was shown to be useful in titrating unknown mutagenic mixtures isolated from environmental samples, yielding stable UV-active adducts (IV-133, IV-134). Although other electrophiles may be reactive with NTP, its selectivity for epoxides and labile halides was demonstrated by mixing several other classes of direct acting mutagens with NTP and checking for loss of mutagenicity in the Ames test; no loss of mutagenicity was observed for 9-aminoacridine, 4-nitroquinoline-1-oxide, 5-nitrofurantoin, and daunorubicin (see Table I-2, Appendix I). Silver nitrate ($AgNO_3$), a classical reagent for detecting labile organic halides (IV-135, IV-136) offered a means of differentiating between organohalide mutagens and other electrophiles reacting with NTP.

Epoxides and organohalides comprise some of the most potent Ames mutagens tested (IV-60). They are also suspected carcinogens and carcinogenic intermediates (IV-126) and have been found in various environmental settings (aflatoxins, mycotoxins, PAH, chlorohydrins, alkylhalides). Because of their health significance and because selective reagents for their detection were available, the epoxides and organohalides became target classes for subsequent experiments with sample residues.

The use of negative ion chemical ionization mass spectrometry for selectively detecting "ultra-trace" levels of electronegative organics, including epoxides and halides, has been well demonstrated in the literature (IV-83, IV-137-IV-140). Therefore, NCI GC/MS supplemented the mutagen assays as a means of following the effects of reacting sample residues with NTP and $AgNO_3$.

Analytical details for derivatization techniques and NCI GC/MS methods are presented in Appendices E and F, respectively. Mutagenic residues from 16 samples were treated with NTP and $AgNO_3$; Ames assays and NCI characterization were performed before and after chemical treatment in order to monitor changes in mutagenicity and the number and concentration of electrophilic compounds resulting from derivatization. Results of the mutagenicity experiments are summarized in Table IV-20. Thirteen of 15 samples showed a reduction in mutagenicity after reaction with at least one of the reagents (one sample was toxic in all aspects of this experiment). Treatment with $AgNO_3$ resulted in a decrease in TA98 mutagenicity for five samples, an increase for four, toxicity in four, and virtually no change in one. Reaction with NTP resulted in a decrease in TA98 mutagenicity for ten residues and an apparent increase for four. All nine samples which were mutagenic on TA100 exhibited a loss of mutagenicity after addition of NTP. No toxicity was attributable to NTP addition, and no pattern of reactivity was discernible based on sample type for either reagent.

TABLE IV-20

MUTAGENICITY OF SAMPLE RESIDUES BEFORE AND AFTER CHEMICAL DERIVATIZATION WITH $AgNO_3$ AND NTP

		TA98			TA100-FRI h/	
Sample Number a/	Sample Type b/	Control c/ (Rev/L)	$AgNO_3$ d/ / Control	NTP d/ / Control	Control c/ (Rev/L)	NTP d/ / Control
35	$UnCl_2$ W	300	0.51	1.5 e/	200	< 0.60
39	Cl_2 W	230	0.78	1.6 e/	320	0.57
44	$UnCl_2$ W	210	0.97	0.8	170	0.68
46	$UnCl_2$ W	220	T f/	-	300	0.30
49	$UnCl_2$ W	470	T	0.8	1220	0.67
52	$UnCl_2$ W	230	T	0.39	320	0.37
53	$UnCl_2$ W	830	T	0.20	530	< 0.50
56	Cl_2 W	400	0.16	0.17	300	< 0.60
57	$UnCl_2$ W	410	0.73	0.46	< 360	N g/
13	Cl_2 3°	T	T	T	T	T
19	$UnCl_2$ 2°	80	2.6	0.6	N	N
47	$UnCl_2$ W	70	1.8	0.7	N	N
48	$UnCl_2$ W	100	0.8	0.9	N	N
65	Cl_2 3°	T	-	0.5	1480	< 0.7
86	Colorado R.	75	1.4	1.3	N	N
87	Storm	1160	3.5	1.5	N	N

a/ For sample listing see Appendix I.

b/ $UnCl_2$ = unchlorinated; Cl_2 = chlorinated; 3° = tertiary effluent; 2° = secondary effluent; W = well.

c/ Residue prior to derivatization.

d/ Ratio of Ames response for derivatized sample and control sample.

e/ Response >1.0 is likely due to residual unreacted NTP, since NTP is weakly mutagenic on TA98.

f/ T = toxic response; for unreacted residue, tested at too high a dose; for $AgNO_3$ treated samples, either AgCl not removed or toxic organic formed.

g/ N = negative Ames test response.

h/ TA100-FRI is a nitro-reductase deficient strain of TA100 used to detect mutagenicity in nitro-containing organics or mixtures which might be elicited by a functional group besides nitro. It was used in these experiments with 4-nitrothiophenol derivatives, since 4-NTP causes mutation in the normal TA100 strain due to the nitro group, and would have masked other results from the experiment.

The molecular effects of the derivatization reactions were followed by NCI GC/MS, from which it became apparent that a significant reduction in NCI-sensitive components resulted from treatment with $AgNO_3$, NTP, or both. Further, computer-extracted ion current profiles (EICPs) for chlorine (m/z = 35,37), bromine (m/z = 79,81), and iodine (m/z = 127) isotopes indicated that as many as 60 to 200 of the reactive organics contained labile halogen; this is illustrated in Figures IV-7 through IV-9 for an unchlorinated well water sample with the EICPs for the halogen isotopes. Although the mere presence of these masses is not necessarily a good measure of the presence of halogen, the fact that the isotope ratios are correct for both Cl (3:1) and Br, (1:1) and that all five masses for Cl, Br and I were reduced by treatment with silver ion, provide strong evidence that these were indeed halogenated organics.

Table IV-21 contains a summary of results from NCI experiments with nine of the 16 samples discussed above. The numbers of major (defined as 20 times background signal, at least five scans wide) GC/MS components containing Cl, Br, and I isotopes which were detected in the nine treated and untreated samples are shown, along with seven reagent and concentrator blanks which illustrate that negligible systematic contamination occurred. For most samples, some reduction in the number of halogenated compounds was observed, although in several cases, an increase in the number of components was detected after treatment with $AgNO_3$ and NTP. The most dramatic increase was seen after treatment of sample No. 48 (Well 2947Q) with $AgNO_3$, which resulted in 12 new major peaks and an eight-fold increase in EICP.

Table IV-22 summarizes the percent removal of Cl, Br, and I ion current by treatment with $AgNO_3$ and NTP. In general, derivatization caused a decrease in halogenated components following the reactivity order I> Br >Cl, which is the expected nucleophilic displacement order for organohalides (IV-135). However, this order is often obscured in Table IV-22 because of the formation of many new compounds during the derivatization step which contributed to the overall halogen ion current. For the silver ion reactions, it may be speculated that secondary rearrangements occurred in the presence of abundant organic matter after the initial halogen abstraction to form silver halide. New components formed in this way may explain the increase in mutagenicity seen for four samples (Table IV-20). For NTP, it is known that stable adducts are formed with epoxy- and halogenated electrophiles (IV-133, IV-134), and that they can be characterized by the ion m/z 154 in NCI. A review of the spectra generated for these NTP-treated samples revealed five samples with new components containing this ion. These include sample No. 87(2 components), No. 19(19 components), No. 86(5 components), No. 48(2 components), and No. 47(4 components). Other adducts may have been formed which were not amenable to gas chromatography.

Each sample also contained components with no apparent halogen which were not altered by $AgNO_3$ or NTP; similarly, there were non-halogenated organics which were reduced by NTP only.

Table IV-22 also contains an estimate of the relative amounts of NCI-sensitive halogenated material. These estimates, which have been corrected for instrument sensitivity and amount of sample used, indicate that the reclaimed water samples tested seemed to have a higher content of organohalides. However, direct assessment of the relative impacts of surface supplies on groundwaters requires traceable compounds.

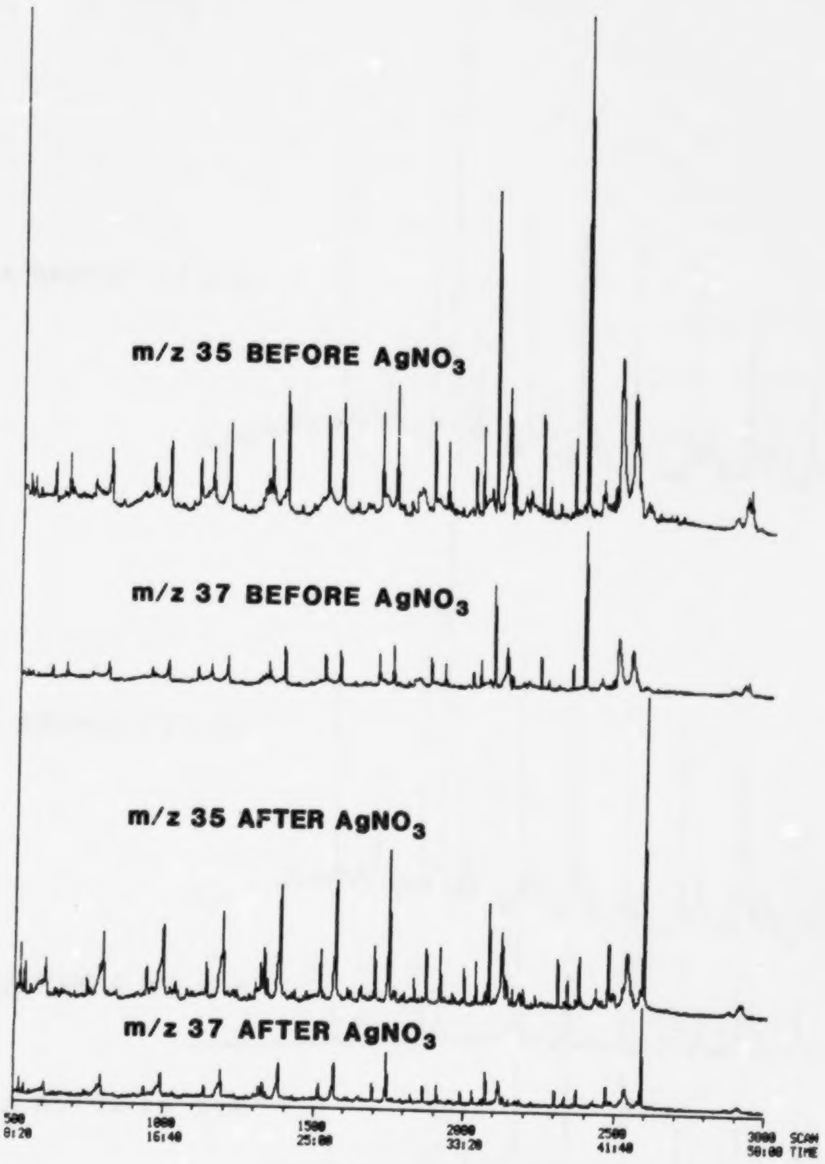


FIGURE IV-7 NCI ION CURRENT PROFILES FOR CHLORINE ISOTOPES 35 AND 37 IN SAMPLE NO. 46 BEFORE AND AFTER DERIVATIZATION WITH SILVER NITRATE

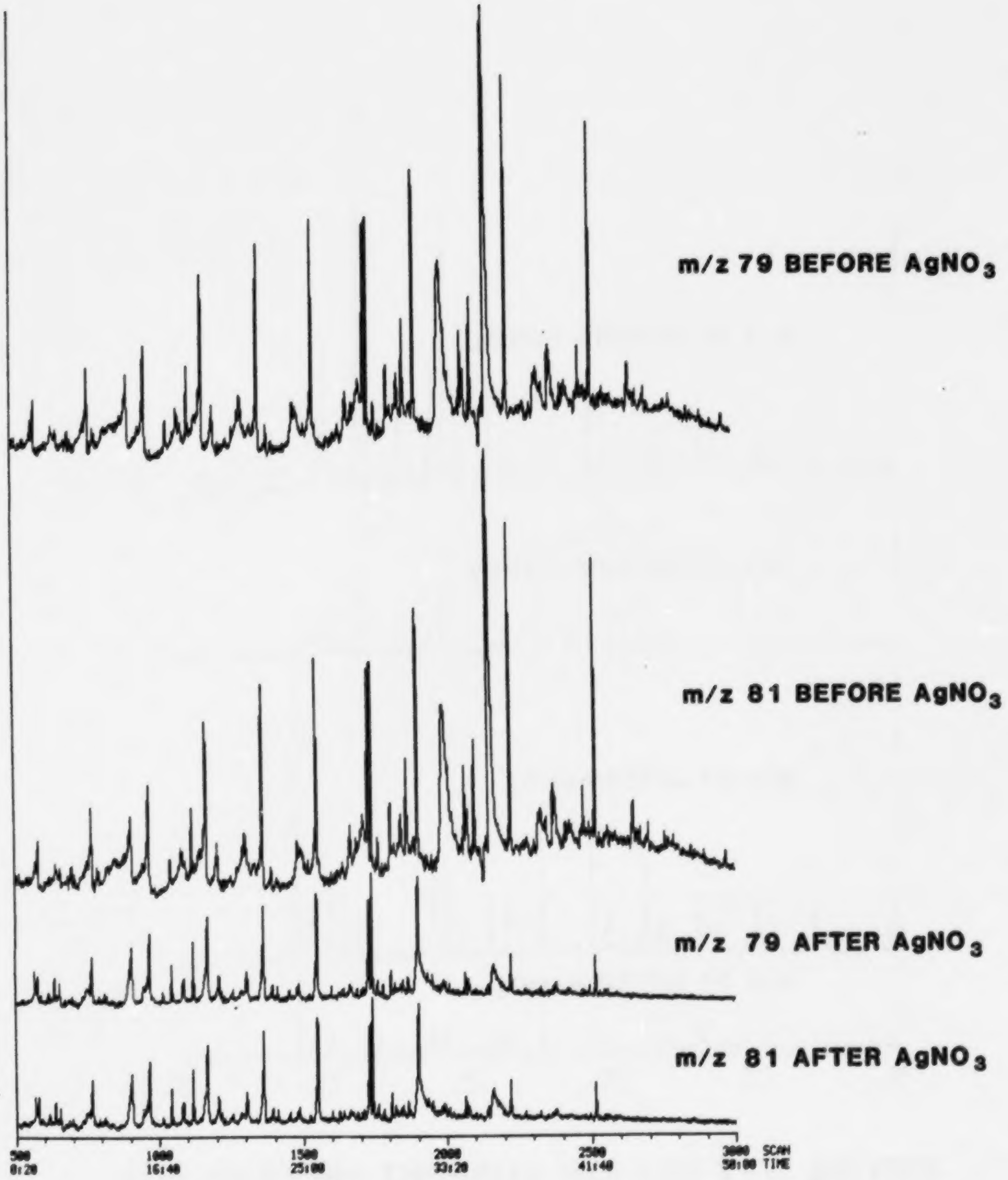


FIGURE IV-8 NCI ION CURRENT PROFILES FOR BROMINE ISOTOPES 79 AND 81 IN SAMPLE NO. 46 BEFORE AND AFTER DERIVATIZATION WITH SILVER NITRATE

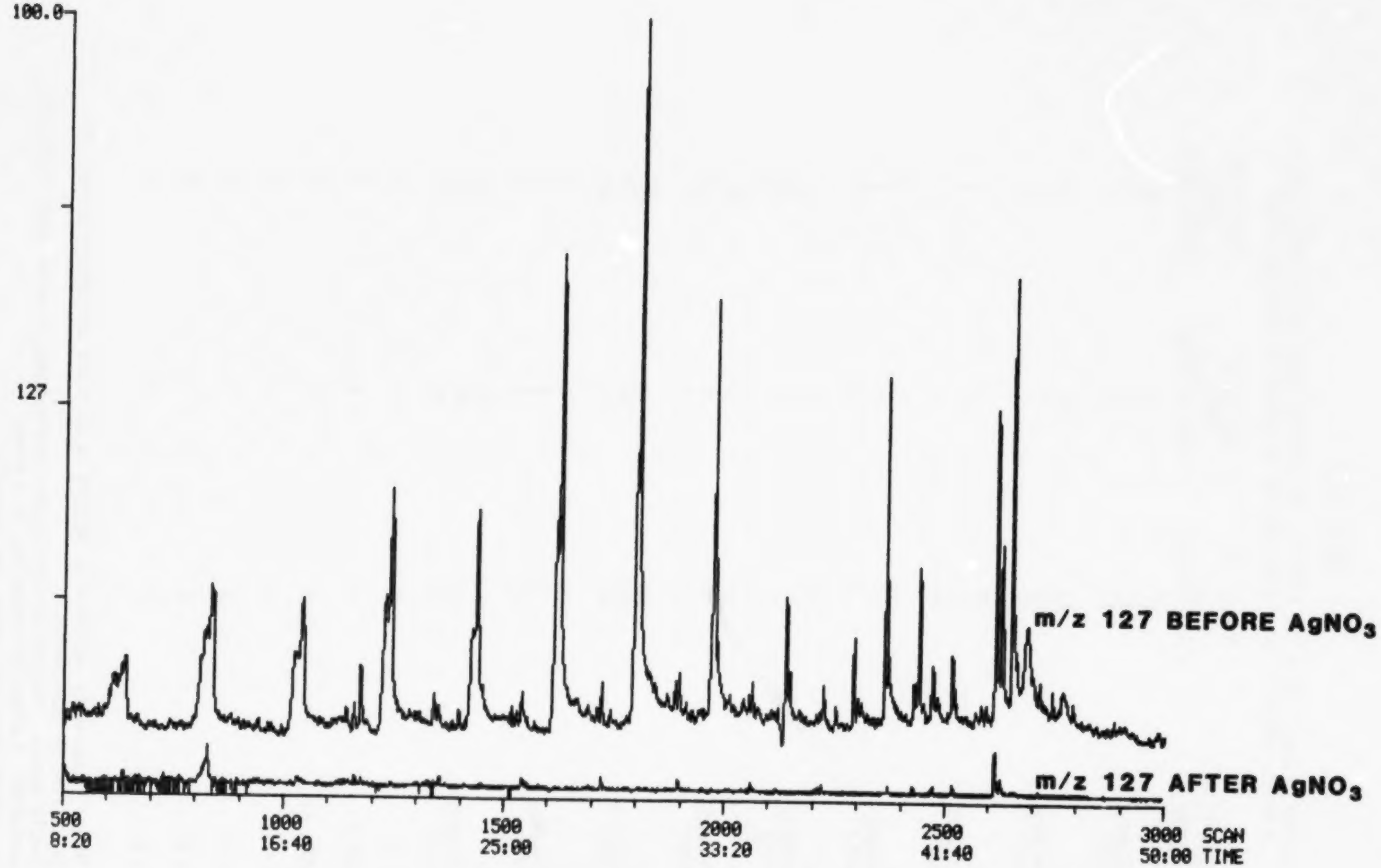


FIGURE IV-9 NCI ION CURRENT PROFILES FOR IODINE ISOTOPE 127 IN SAMPLE NO. 46 BEFORE AND AFTER DERIVATIZATION WITH SILVER NITRATE

TABLE IV-21

NUMBER OF MAJOR NEGATIVE CHEMICAL IONIZATION GC/MS PEAKS CONTAINING CHLORINE, BROMINE, AND IODINE BEFORE AND AFTER DERIVATIZATION a/

Sample b/,c/ Number	Number of Peaks with Chlorine	Number of Peaks with Bromine	Number of Peaks with Iodine
46	41	5	22
46+$AgNO_3$	17	2	2
46+NTP	14	1	7
47	19	13	4
47+$AgNO_3$	16	1	1
47+NTP	19	3	8
48	25	3	0
48+$AgNO_3$	37	10	3
48+NTP	22	2	2
56	9	0	0
56+$AgNO_3$	6	0	1
56+NTP	0	0	0
86	34	11	7
86+$AgNO_3$	27	7	8
86+NTP	35	11	12
87	19	1	21
87+$AgNO_3$	1	5	3
87+NTP	5	3	17
19	35	13	21
19+$AgNO_3$	22	15	9
19+NTP	44	11	19
59	13	6	5
59+$AgNO_3$	9	4	9
59+NTP	12	5	3
13	70	47	22
13+$AgNO_3$	54	38	15
13+NTP	46	27	17
91 Bl	0	0	0
K-27 Bl	0	6	8
$AgNO_3$ Bl	0	1	0
NTP Bl	0	0	0
48 Bl	1	3	0
56 Bl	1	2	0
74 Bl	1	0	0

a/ "Major" components arbitrarily defined as 20 times background signal, at least five MS scans wide.

b/ Sample number - before derivatization; number/$AgNO_3$ = after $AgNO_3$ reaction; number/NTP = after NTP reaction; Bl = blank.

c/ For sample cross reference, see Appendix I.

TABLE IV-22

REMOVAL OF HALOGENATED COMPONENTS AFTER TREATMENT WITH SILVER NITRATE AND 4-NITROTHIOPHENOL

Sample a/ Number	Relative Halogen Content b/	Percent Ion Current Decrease For Halogen Isotope					
		$AgNO_3$			NTP		
		Cl	Br	I	Cl	Br	I
46	42.9	77	88	97	85	97	86
47	16.8	43	91	96	13	77	27
48	5.9	c/	c/	c/	39	41	d/
56	1.0	42	d/	d/	100	d/	d/
86	22.7	6	41	13	21	9	38
87	27.2	95	70	91	85	35	50
19	182	c/	61	19	c/	41	27
59	76	87	72	78	60	55	70
13	895	68	91	82	71	87	81
	Average	52	63	68	58	55	54

a/ See Appendix I for sample number and sample type reference.

b/ Total halogen ion current in unreacted sample, normalized for sample volume taken, amount injected into GC/MS, and MS calibration on day of injection; lowest ion current for sample No. 56 fixed at unity (1.0) for normalizing relative halogen content.

c/ New halogenated components resulted from derivatization reaction, causing ion current to increase relative to unreacted sample.

d/ No isotopes detected in unreacted sample obviating percent removal calculation.

Table IV-23 contains a series of major NCI peaks (listed by MS scan numbers), each of which was found in two or more Montebello Forebay sources. Initially, peaks of less than 10,000 ion counts or less than 10 percent of the ion current in its respective sample were discriminated against. Subsequently, samples were reviewed to determine if major components found in groundwater samples were present in source waters at levels less than the above criteria. This procedure resulted in identification of 12 components present in at least one source water and one groundwater, two components present in groundwater only, and one compound found only in percolation sources. Subtracting DEHP (scan 2929), an unknown peak common to all sample sources (m/z = 216, scan 2120), and the component which did not react with $AgNO_3$ or NTP, there are at least 12 compounds in these samples which can be suspected as being mutagens. Of these, nine were present in at least one source water and one groundwater.

Molecular identification of unknowns from NCI spectra alone is normally not feasible because very little fragmentation occurs, and spectral compendia are not available. In order to be able to assess NCI spectra of unknown organohalides in the context of aqueous environmental research, a library of halogenated organics (and mass spectra when available) was compiled from data reported in the water chlorination literature. These are listed in Appendix L by molecular weight. The apparent molecular weight from each scan in Table IV-23 was checked against this library; candidate compounds (and EI spectral information when provided) were then extracted for further work. EI spectra generated in the fractionation/bioassay iteration were reviewed to see if EI spectra could be extracted for comparison of unknowns to known organics. GC retention times for authentic compounds, when available, were compared to retention times for unknowns, and NCI spectra were generated for these standards.

To date, this process has not resulted in positive identification of any of the unknowns. However, Table IV-24 lists those candidates which have not yet been eliminated, along with those components which cannot be identified, and the most abundant mass ions of the unknowns.

It has been established that water chlorination often increases the mutagenicity of environmental samples (IV-99, IV-109). However, direct evidence for the role of halogenated mutagens in such samples has seldom been presented, and in only a few instances have new compounds been suggested as the cause (IV-99, IV-141, IV-142).

The fact that the experimental results presented here are consistent with the presence of many mutagenic organohalides, and that none have yet been identified, must raise the question regarding possible sources of such a plethora of possible health significant compounds. Unfortunately, even though these data suggest that a chemical basis for the mutagenicity exists, and many origins are possible, current information is not definitive. Since most of the source waters studied are routinely chlorinated, deliberate water chlorination may be a cause. Imported water is often spot-chlorinated during distribution and reclaimed waters are disinfected with chlorine (usually chloramine residual) prior to discharge. In addition, many groundwaters are disinfected with chlorine prior to distribution. In industry, chlorine finds major use as an anti-fouling agent in cooling waters, as a bleaching agent in the textile and paper industries, and as an oxidizer in metal finishing industries. All of these practices produce stable halogenated by-products, and some are known to produce mutagens (see references in Appendix L).

TABLE IV-23

MAJOR NEGATIVE CHEMICAL IONIZATION GC/MS SCANS COMMON TO TWO OR MORE MONTEBELLO FOREBAY SAMPLES

SAMPLE NUMBER AND SOURCE a/,b/								NCI DATA		DERIVATIZATION REACTION c/		
59	19	87	86	46	47	48	56	BASE	OTHER			NOTES
SJC $DeCl_2$ 3°	SJC $UnCl_2$ 2°	Storm Water	Colorado River Water	Well 1620GG $UnCl_2$	Well 1562E $UnCl_2$	Well 2947Q $UnCl_2$ (control)	Well 2958A Cl_2	m/z	m/z	$AgNO_3$	4-NTP	
	1303	(1304)	1186 1302	1183 (1312)			1306	218	179	+	-	not NTP reactive
	1363						1359	35	37,79,81	+	+	
	1646				1646							no match
				1866			1866					no match
		2027		2024								no match
	2119	2123	2120	2116	2120	2120		216		-	-	See Table IV-17
		(2133)	(2136)	2133	2136	2135	2134	216	35,37	+	+	
		2151			2150							no match
2165	2166	2164		2165				264	294	-	-	
	2208	(2212)	2208		(2207)			96	64,128	-	+	no halogen
				2377	(2370)	2377	2374	232	35,37	+	+	
	(2444)				2442	2442	2441	35	37,249,262	+	+	
	2494	2490	2493			2495		35	212,302,127	+	+	
(2532)			(2528)	2532			2532	35	37,79,81	+	+	
(2536)			2538		2537	2536		35	37	+	+	
(2542)	2542	(2543)	2543	2542	2542	2541		35	37	+	+	
				2588	2586	2587	2588	265	35,37	+	+	
				(2614)	2609	2611		79	81,127,298,300,302	+	+	
2929	2922	2925	2924	2920	2924	2920	2916	148	166,232,278	-	-	DEHP

a/ $UnCl_2$ = unchlorinated; Cl_2 = chlorinated; $DeCl_2$ = dechlorinated; SJC 3° = San Jose Creek WRP tertiary effluent; SJC 2° = San Jose Creek secondary effluent.

b/ Underlined scans were visually matched as same component in different samples; components not matching are not underlined; parentheses indicate component was <10,000 ion counts or less than 10 percent of total ion current in respective sample.

c/ (+) indicates reaction occurred, i.e., partial or total loss of component peak at indicated scan; (-) indicates no reaction.

TABLE IV-24

CROSS REFERENCE OF COMPONENTS IN TABLE IV-23 TO HALOGENATED ORGANICS IN APPENDIX L

Scan Number	NCI Base Peak m/z	Other NCI Peaks m/z	EI Peaks a/ (m/z)	Candidate Identification from Table IV-25 (MW) b/
1303	218	179	133,105,77, 79	dichloro-8-hydroxycymene (217); chloromethylpropylnapthalene (218); chlorodibenzo-p-dioxin (218)
1368	35	37,79, 81		unknown
2133	216	35,37		chlorosyringaldehyde(216); dichloro-8-hydroxycymene(217)
2165	264	294		unknown
2208	96	64,128		unknown (not halogenated)
2377	232	35,37	232,202 184,186, 174,93	unknown
2444	35	37,249, 262	316,318, 246,248, 176	unknown
2494	35	37,127, 212,302		chlorodiiodomethane(302)
2532	35	37,79, 81		unknown
2536	35	37		unknown
2542	35	37		unknown
2614	79	81,127, 298,300, 302		dibromoiodomethane(298)

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a/ EI spectra were only available for a few NCI components since most of the latter were not detectable in the EI mode.

b/ Compound with molecular weights in parentheses obtained from Appendix L; standards or authentic spectra not available for refuting or verifying possible identifications shown.

Several mechanisms for aqueous halogenation reactions in the presence of chlorine are known. The haloform reaction is a facile pathway to production of chlorinated, brominated, and iodinated methanes (including chloroform) from diketones and polyhydroxy aromatics in the presence of free chlorine and bromide and iodide ions (IV-64, IV-143-IV-145). Halohydrin formation occurs by aqueous addition of halogen to carbon-carbon double bonds (IV-135). Halogenation of amine nitrogen, including ammonia, aromatic amines, and amino acids has been studied extensively (IV-146-IV-152); participation of haloamines in subsequent halogenation reactions cannot be ruled out, especially for bromide and iodide substitutions. In addition, evidence has been presented for aromatic ring halogenation of arenes and polyphenyl structures (IV-135, IV-153, IV-154). Some products from all of these types of reactions are known to be alkylating mutagens (IV-78, IV-126, IV-155), and one comparison of brominated and chlorinated aliphatics showed that all the brominated derivatives were more mutagenic than the chlorinated analogs (IV-158). Biological production of these low level halogenated organics is also a distinct possibility, a subject recently reviewed by Siuda (IV-160). The number of naturally occurring halogenated compounds has been estimated at more than 550, representing biological production by more than 200 distinct species from man to microbes (IV-160). In most known cases, biological halogenation processes appear to be mediated by a class of enzyme known as haloperoxidases, which possess chlorinating, brominating, iodinating, and peroxidizing capabilities (IV-160). In addition, biological transformation reactions of halogenated organics under a variety of conditions have been reported (IV-161), IV-162) and reviewed (IV-163-IV-165).

With regard to the apparent contribution to mutagenicity of non-halogenated NTP-reactive species, several sources of epoxides are plausible. Natural products such as aflatoxin and other mycotoxins form mutagenic diol- and epoxy-intermediates (IV-126, IV-131, IV-132). PAHs like benzo(a)pyrene are also precursors to mutagenic diol- and epoxy- intermediates (IV-61). Chemical or biochemical halohydrin elimination reactions have been suggested as routes to epoxide formation (IV-135, IV-156). The genetic toxicity of epoxides and halohydrins (halo-alcohols) has been reviewed (IV-166), as well as the role of biological organisms. One class of mutagens, the alkylene halohydrins, appear as products of the reaction of epoxides with halide ion in foods, in the stomach, and in blood (IV-166). Mutagenicity of brominated and iodinated species was greater than the mutagenicity of chlorinated analogs. Although some halohydrins and epoxides have been shown to be persistent enough to cause animal tumors, ethylene halohydrins were not (IV-166).

DISCUSSION OF POSSIBLE HEALTH SIGNIFICANCE

Introduction

Estimation of any possible human health significance posed by the findings presented in this report requires a discussion of risk assessment. The process of risk assessment has been evaluated in detail by a National Research Council Committee (IV-167), which stated that there are two distinct elements upon which health-related regulatory actions are based: (1) risk assessment, and (2) risk management. By definition, risk assessment is the use of scientific data to determine the health effects of human exposure to hazardous materials, whereas risk management is the process of integrating the assessment with policy alternatives, engineering data, and economic, social, and political concerns for selecting the most appropriate action. Focussing on the former, the committee identified four steps making up the risk assessment process, one or more of which may be taken for the purpose of various assessments:

(1) hazard identification: the determination of whether or not a particular chemical causes a specific health effect; involves description of the validity and strength of the evidence.

(2) dose response assessment: determination of the relation between the magnitude of exposure to a chemical and the probability that a specific health effect will occur; usually requires extrapolation from high to very low test doses, and extrapolation from animals to humans.

(3) exposure assessment: determination of the mode and the extent of human exposure with or without regulatory control.

(4) risk characterization: qualitative or quantitative description of the human risk, including uncertainty; performed by combining steps two and three.

Use of these steps to describe potential adverse health effects relies on evaluation of scientific results from epidemiology, toxicology, and clinical and environmental research. Usually, risks must be extrapolated from research results to specific human exposure conditions, an exercise which requires expert judgement and careful characterization of the uncertainties involved.

Historically, regulatory programs addressed exposure to toxic chemicals which would cause "poisoning" or other acute effects. The attendent risk assessments were based upon conventional short term animal tests to determine the "no observed effect levels", followed by a straight-forward calculation of permissable human exposure, including a safety factor to account for uncertainty. This work lead to the development of lists of chemicals with "known" health effects and environmental limits corresponding to calculated no observed effect levels. As technological advances facilitated measurement of lower levels of chemicals and detection of chronic effects from lower doses of toxicants, scientific, public, and regulatory attention has concentrated on health problems such as cancer and birth defects. Four major agencies, the Environmental Protection Agency, Food and Drug Administration, Occupational Safety and Health Administration, and Consumer Product Safety Commission, now have mandated activities focused on chronic health hazards, with an emphasis on cancer (IV-167).

Several facts regarding cancer as a disease make implementation of the steps to carcinogen risk assessment a difficult task. First, a biological mechanism for cancer is not known. Second, the time-to-tumor following exposure to a carcinogenic agent (latency period), is probably long in humans--perhaps 10 to 20 years or more. Third, incidences of human exposure to carcinogens suitable for epidemiologic determination of human carcinogenicity are few, and experimentation with humans is not feasible. This requires testing of many hundreds of compounds using surrogate animal species. Finally, the range of potency of animal carcinogens is known to be a million-fold, and the pharmacokinetics of individual carcinogens in animals (including humans) are incompletely known.

In spite of these difficulties, there is a scientific basis for carcinogenic risk assessment, which can be described in relation to the four steps of risk assessment as follows:

Hazard Identification. Information arising from four areas of science (epidemiology, animal bioassays, *in vitro* bioassays, and molecular structure comparisons) are available for hazard identification. The most convincing evidence establishing a positive association between a chemical agent and human disease (emphasis on cancer) comes from appropriately conducted epidemiology studies. However, most environmental chemicals have not (and may never be) studied by epidemiologic methods. This and other limitations of epidemiology which have been reviewed in Chapter VII and elsewhere (IV-167) necessitate reliance on less direct evidence that a hazard exists such as the results of animal bioassays. The premise that toxicologic response in animals is relevant to similar response in humans is a fundamental precept of toxicology, experimental biology, and medicine; there is sound scientific evidence supporting this link for cancer specifically. In spite of the general validity of this precept, there are some pitfalls associated with animal testing and indiscriminate extrapolation of animal data to humans; these have been reviewed (IV-167-IV-169), and play an important role in governing risk assessments.

Short term bioassays such as bacterial mutagen tests, mammalian cell transformation tests, and other *in vitro* assays provide experimental support to animal bioassays of carcinogenicity. The concept that most chemical carcinogens are mutagens and that many mutagens are carcinogens is well accepted (IV-60), and provides the basis for use of short term tests for risk assessment. It is important to note that *in vitro* bioassay data, in the absence of positive animal bioassays, are not considered to be sufficient to establish that a substance is carcinogenic (IV-170). Additional supporting information regarding a chemical's potential as a carcinogen comes from comparison of molecular structure with known carcinogens. Again, these data must eventually be coupled with the appropriate animal bioassays.

Dose Response Assessment. Assessment of human dose-response to chemical carcinogens is currently the focal point for much controversy when used for quantitative risk assessment. Since epidemiologic data are seldom able to be used directly in dose-response determinations, there are few chemicals for which human data exist. For carcinogens, human dose response assessment usually requires extrapolation from tests on animals; however, these bioassays are typically designed for hazard identification rather than dose-response evaluations. For the latter case, modern testing protocols call for testing at least two animal species at a high dose (maximal tolerated dose not causing acute toxicity), at one half this dose, and at zero dose (control).

The philosophy behind the maximal dose is to optimize the sensitivity of the assay. The shortcomings of this practice for some chemicals have been enumerated and reviewed (IV-167, IV-169, IV-171). These include the possibility that maximal doses overwhelm normal metabolic functions which could otherwise detoxify the chemical being tested, inter-species differences in metabolism, use of administered dose rather than tissue dose for determining dose-response relationships, and the fact that doses of environmental interest are typically much lower than test doses. The principal application of the concept of increased response to increased dose in most animals studies is to corroborate identification of a carcinogenic hazard, rather than to develop detailed dose assessment data.

Quantitative risk assessment requires extrapolation from test doses to very low doses by fitting mathematical models to available animal dose response data. The purpose is to predict human risk at low doses corresponding to possible environmental exposure. The statistical problems of evaluating low dose-response outcomes with bioassays have been reviewed (IV-171). Basically, the problems result because induced tumor response of less than five percent in animal bioassays is usually not statistically demonstrable due to the small animal populations normally used, whereas regulatory agencies are concerned with environmental doses which may correspond to risks of from one extra case of cancer in 1000 (10^{-3}) people to one in a million (10^{-6}) people. Because the shape of the dose response curve at several orders of magnitude below the testing range cannot be determined experimentally, several mathematical methods have been developed to extrapolate from high to low dose (IV-12, IV-167, IV-168, IV-169). These models have varying degrees of biological plausibility (some have none). Often the modeling includes an adjustment to allow for differences in size and metabolic rates for test animals and humans. Currently, the linear multi-stage, no threshold model is the model of choice by the NAS, EPA, and others (IV-12, IV-57, IV-167). This model assumes that: 1) cancer is a multistage biological process, 2) there is no safe "threshold" dose below which genetic damage will not occur, and 3) with the proper adjustment for inter-species difference, human risk may be estimated by linear extrapolation from test dose response data in animals.

Although some of the features of this method of risk quantification are open to scientific challenge, (notably the no-threshold theory of carcinogenicity) it represents the most conservative or prudent assessment of theoretical risk for use by public health officials, given the current state of scientific uncertainty about cancer as a disease.

Exposure Assessment. Determination of the extent of human population exposure to a chemical may come from direct measurement, or most frequently, from estimation models. Exposure measurements for small groups are sometimes extrapolated to larger populations in communities. Environmental exposure can only be estimated if environmental emission rates, and transport and conversion processes in the community are known (IV-167). Control options require that estimates of reduction in exposure resulting from control be derived. Patterns of exposure, alternate sources of a chemical, and variability in population subgroups may all be important factors in a given exposure assessment. In addition, the possible exposure to multiple (mixtures of) carcinogenic agents in a given environmental setting is an important factor because of the possibility of synergistic effects. Although current dose response data and models cannot quantitatively assign risk arising from synergism between chemicals, use of various "safety factors" in risk assessment calculations are sometimes used to account for the possible effects. In practice, risks from multiple chemicals are often added (IV-174). Exposure assessment models used by EPA and NAS (IV-12, IV-57) for drinking water exposure to carcinogens currently estimate risk based on lifetime (70 years) exposure from consumption of one or two liters of drinking water per day. For chemicals that can accumulate in food supplies, adjustments are also described for the consumption of an average daily amount (18.7 g) of fish (IV-57).

Risk Characterization. Risk characterization is the estimate of the magnitude of the health risk experienced by the human population exposed to a given agent. The process involves combining dose response and exposure assessments in a manner consistent with the scientific data and and scientific guidelines employed in those steps. There appears, as yet, to be little specific guidance on how to express the underlying uncertainties in the data and models used to give a final estimate of risk from those two steps (IV-167).

Risk Assessment Guidelines and Regulation

Risk assessment guidelines, regulatory statutes related to the protection of public health, and the role of the four federal agencies with major responsibilities for control of trace chemicals have been reviewed by NAS (IV-167). The discussion in this section will be restricted to water-borne contaminants and the role of the Environmental Protection Agency; the activities of an ad hoc National Academy of Sciences/National Research Council committee and the California Department of Health Services will also be presented.

Environmental Protection Agency. Within the EPA, risk assessment and risk management are organizationally separate functions. Carcinogenic risk assessment is carried out by the Carcinogen Assessment Group (CAG), even though the CAG coexists as one of several groups within EPA and provides risk assessment for several different EPA regulatory programs. In this capacity CAG responds to requests from the different regulatory offices. Risk assessment documents prepared by CAG are submitted to outside peer review, but not as part of a formalized process (IV-167).

EPA is constrained by several legal provisions (e.g., Safe Drinking Water Act) to balance regulatory costs and benefits with risk assessments in setting standards - in essence, a risk management process. In addition, a portion of the clean water program involves establishment of a technology-based set of exposure controls, and risk assessments may be used to show the human health benefit of implementation of these. As a result of the evolution of these types of mandated activities, EPA adopted formal guidelines for carcinogenic risk assessment in 1976 (IV-167) which involved a two phase process. The first step is hazard identification as described earlier in this discussion. The second was determination of what regulatory action, if any, should be taken (quantitative risk assessment was explicity included in this phase). The guidelines are not regulations, but rather, are recommendations addressing a few components of the four steps of risk assessment. More detailed guidelines for risk assessment relying in part on the Interagency Regulatory Liaison Group (IRLG) guidelines were published for review by EPA in 1980 (IV-167). The IRLG guidelines themselves, while having no official legal status, were an indication that all four major federal agencies agreed on a set of guidelines for hazard identification and risk estimation and seem to indicate that quantitative risk assessment was to play a priority-setting role in regulatory activities (IV-167).

National Academy of Sciences/National Research Council. The Safe Drinking Water Committee of the NAS/NRC was established separately from government regulating agencies. Studies of the Committee were initiated to meet the mandate of the Safe Drinking Water Act, with its findings advisory in nature. Committee members, appointed on the strength of professional qualifications, were selected from university, industrial, and government sectors. The work of the Committee has been published (IV-11, IV-12, IV-179), and includes hazard identification, toxicological action reviews, risk assessment calculations for some carcinogens, acceptable daily intake/no adverse response levels for non-carcinogens, and discussion of the data bases, models, routes, and uncertainties attending their findings. Variations in water intake and nutritional requirements were also discussed; economic factors were not considered. The reports of this Committee, as with other NAS/NRC committees, are subject to formal peer review (IV-167).

California Department of Health Services. The California Department of Health Services (DOHS) has published guidelines concerning its proposed carcinogen identification policy (IV-172, 173, 174). The purpose of the guidelines is to serve as a basis for future DOHS (and other state agencies') actions when a carcinogenic risk is identified. The overall goal of the policy is "to decrease human exposure to carcinogens", hence decreasing the risk of cancer. The policy framework was designed to be flexible enough to consider the latest scientific information, to develop priority lists of chemicals for intervention, and when appropriate, establish the basis for regulation by the appropriate state agency. The policy includes a list of carcinogens identified by the National Cancer Institute, National Toxicology Program and the International Agency for Research on Cancer (IV-174). It also establishes priority lists for "actionable" chemicals and ranks carcinogens according to potency. Implicit in this policy is eventual determination of theoretical cancer risks, definition of generic science policy issues and terminology, mechanisms for hazard evaluation, intervention actions (including regulations), and means of dealing with requests for regulatory action.

Discussion of Trace Organic Data

Table IV-25 summarizes risk assessment data (EPA Water Quality Criteria), DOHS action levels, EPA primary drinking water maximum contaminant levels, and NAS suggested no-adverse response levels (SNARLs) that exist for the target organic chemicals quantified during the Health Effects Study. The Water Quality Criteria were calculated from animal data for the theoretical 10^{-5} risk level; EPA also presented a linear extrapolation of these to the 10^{-6} and 10^{-7} risk levels (IV-57). California DOHS action levels which now exist for carbon tetrachloride, trichloroethylene, and tetrachloroethylene were set at a 10^{-6} risk level. It is of interest to note that the State's proposed cancer policy also selects the 10^{-6} risk level as the "actionable" level for other carcinogens, "consistent with the protection of human health" (IV-174). The NAS SNARLs are given for short term (7-day) and chronic exposure. The short term values were determined directly from animal toxicology for non-carcinogenic effects, and were intended for accidental exposure to chemicals (e.g., spills). The chronic SNARLs were determined for non-carcinogenic effects if 20 percent of the acceptable daily intake was from water. For animal carcinogens (suspected human carcinogens), the cancer risk was calculated from available dose-response animal tests evaluated by the NAS Committee (IV-12). No chronic SNARLs were

TABLE IV-25

RISK ASSESSMENT AND DRINKING WATER LIMITS FOR TARGET ORGANICS

Compound	NAS 7-Day SNARL a/ μg/L	NAS Chronic SNARL or 10^{-6} Cancer Risk a/ b/ μg/L	DOHS Action Levels c/ μg/L	EPA MCLs d/ μg/L	EPA Water Quality Criteria μg/L
vinyl chloride	-	1.96 b/	-	1-100 f/	20.0
methylene chloride	5,000	g/	-	-	-
chloroform	3,200	3.12 b/	-	100 h/	1.9 h/
bromodichloromethane	g/	g/	-	100 h/	1.9 h/
dibromochloromethane	g/	g/	-	100 h/	1.9 h/
bromoform	g/	g/	-	100 h/	1.9 h/
carbon tetrachloride	2,000	6.67 b/	5	5-500 f/	4.0
1,1-dichlorethane	-	g/	-	-	-
1,2-dichloroethane	g/	1.42 b/	-	1-100 f/	9.4
1,1,2-trichloroethane	-	-	-	-	6.0
trichloroethylene	15,000	g/	5	5-500 f/	27.0
tetrachloroethylene	24,500	7.14 b/	4	5-500 f/	8.0
chlorobenzene	-	-	-	-	488/20 i/
1,4-dichlorobenzene	-	-	-	-	400 i/
1,2-dichlorobenzene	-	-	-	-	400 j/
benzene	250	k/	-	-	6.6
toluene	35,000	340 a/	-	-	14,300 l/
DDT	-	8.33×10^{-2} b/	-	-	2.4×10^{-4}
dieldrin	-	3.84×10^{-3} b/	-	-	7.1×10^{-4}
aldrin	-	1.07×10^{-1} b/	-	-	7.4×10^{-4}
lindane	500	m/	-	4	1.9×10^{-1}
atrazine	-	150 n/	-	-	-
simazine	-	1,505 n/	-	-	-
pentachlorophenol	-	21 n/	-	-	1,010/30 i/
trichlorobiphenyls (as total PCB)	50 o/	m/	-	-	7.9×10^{-4}
tetrachlorobiphenyls (as total PCB)	50 o/	m/	-	-	7.9×10^{-4}
trichlorobenzene (1,2,4-isomer)	-	-	-	-	-
trichlorophenol (2,4,6-isomer)	2,500	m/	-	-	12
trichlorophenol (2,4,5-isomer)	-	-	-	-	2,600/1.0 i/
bis-(2-ethylhexyl)phthalate	-	4,200 n/	-	-	15,000 l/
phenylacetic acid	-	-	-	-	-
fluoranthene	-	-	-	-	42 l/
phenanthrene	-	-	-	-	-
benzo(a)pyrene	g/	m/	-	-	2.8×10^{-3}

a/ National Academy of Sciences, suggested-no-adverse-response-levels for seven day exposure and chronic exposure; References IV-11, IV-12, IV-179.

b/ National Academy of Sciences, concentration corresponding to 10^{-6} cancer risk; References IV-11, IV-12.

c/ California Department of Health Services action levels; Reference IV-157.

d/ EPA maximum contaminant levels; References IV-65, IV-180.

e/ EPA Water Quality Criteria for the protection of human health based on exposure by ingestion of water and aquatic products; except where noted as ambient concentrations, these criteria correspond to an excess cancer risk of 10^{-5}; Reference IV-58.

f/ Proposed maximum contaminant levels; Reference IV-66.

g/ Concentration not derived due to lack of adequate data.

h/ For total trihalomethanes (chloroform, bromoform, dibromochloromethane, bromodichloromethane).

i/ Ambient water concentrations associated with toxic/organoleptic effects.

j/ Ambient water concentration for combined dichlorobenzenes.

k/ Compound is implicated as a lukemogen, hence no acceptable dose can be determined.

l/ Ambient water concentration.

m/ Compound is implicated as a carcinogen, hence no acceptable dose can be determined.

n/ National Academy of Sciences suggested-no-adverse-response-level assuming 20 percent of the acceptable daily intake is from water; References IV-11.

o/ For total polychlorinated biphenyls.

proposed for suspected carcinogens or compounds requiring additional testing to verify carcinogenicity. The EPA MCLs for drinking water were promulgated for trihalomethanes and a few selected pesticides. A range of concentrations for some additional organics has also been proposed for review as MCLs (IV-66). At this time the MCLs are the only federal drinking water standards imposed for trace organics, and as mentioned earlier, were based on available scientific data (theoretical risk assessment data) as well as the economic costs and benefits of regulation.

According to the information shown in Table IV-25, none of the Montebello Forebay well water samples presented a problem as far as the MCLs, 7-day SNARLs, or chronic SNARLs for organics were concerned. Furthermore, none of the unchlorinated wells presented concern when evaluated in terms of the NAS or EPA theoretical models for excess cancer risk or the DOHS action levels shown in Table IV-25. The chlorinated wells contained THM levels exceeding the EPA Water Quality Criteria in four of the six samples taken.

In the San Fernando Basin, the wells sampled frequently had trichloroethylene or tetrachloroethylene exceeding NAS, EPA, or DOHS risk guidelines. Unchlorinated wells in the Anaheim Forebay did not exceed any of the risk assessment guidelines in Table IV-25, although the one chlorinated well sampled consistently exceeded the EPA Water Quality Criteria for THMs. The Talbert Barrier wells also exceeded the Water Quality Criteria for THMs.

Evaluation of groundwater replenishment sources in the Montebello Forebay showed that none of the reclaimed water, imported water, or storm water samples exceeded the MCLs, 7-day SNARLs or chronic SNARLs for organics. However, reclaimed waters often contained either THMs, TCE, PCE, carbon tetrachloride, or 1,2-dichloroethane at a level in excess of one or more of the agency risk criteria shown in Table IV-25. Storm water showed a potential for exceeding action levels for PCE. Reclaimed water samples in the Montebello Forebay also sporadically showed either lindane, DDT, dieldrin, aldrin, or PCB in excess of the EPA Water Quality Criteria. Colorado River water consistently contained THMs in excess of the EPA Water Quality Criteria, and in one instance also had DDT and dieldrin in excess of these guidelines.

From a human health standpoint, the groundwater replenishment program in the Montebello Forebay, using source waters which frequently contained one or more organic chemicals exceeding theoretical risk levels, appears to have had an insignificant effect on potable groundwaters. The effects of source dilution (proportioning) and/or soil attenuation have been reflected in the maintenance of groundwater quality. Even though invocation of risk assessment steps 1-3 can support these statements, some uncertainties need to be brought forth, since different interpretations might change the risk characterization and may ultimately play a role in future water reclamation regulations and management. The first point is that the data base for this discussion comes from three samples collected from each of the ten wells of interest, taken over a two year period. The fact that trace organics in source waters can also be detected (albeit at concentrations below assigned risk estimates) in groundwaters suggest that continued monitoring of the groundwaters for target organics is necessary to increase the confidence level of the data base. The result of such monitoring may or may not change the risk characterization stated above. Related to the size of the data base is a question regarding the relative effects of the different surface sources used in groundwater replenishment on estimated risks. Determination of relative contributions of specific organics from these different sources would be significantly aided by a broader data base for calculation of mass inputs. Reasonable management scenarios for groundwater replenishment operations might impose one type of restriction on one source and another restriction on a different source for regulating mass inputs to the groundwater. The application of various treatment scenarios (e.g., for chlorine disinfection of drinking water or chlorination of industrial wastes) would also alter risk management decisions for potable water use and groundwater replenishment operations.

Another area of uncertainty relates to the state of scientific knowledge and judgement. Discovery of new toxicological information on particular chemicals, the carcinogenesis process, or better risk models could certainly alter the theoretical risk assessment outcome for well waters or any of the replenishment sources. An example of new toxicological information which could change the existing risk assessment involves bis-(2-ethylhexyl) phthalate (DEHP) which has recently been determined to be an animal carcinogen in the National Toxicology Program (IV-159). Although no theoretical risk levels or action levels have been projected yet, the ubiquity of the compound in Health Effects Study samples could ultimately have a significant impact on any risk characterization of water reuse. Another example relates to improvement in analytical techniques which could reveal the presence of materials at theoretical risk levels. This point is relevant to the study findings, since detection limits for some pesticides are not good enough to insure compliance with the respective Water Quality Criteria.

Of potentially great impact on risk characterization and management are changes in, or implementation of new guidelines for risk assessment. For example, the California DOHS is considering using the 10^{-6} excess cancer risk level as the "actionable" level for known and suspected carcinogens. If these 10^{-6} values are obtained by simply extrapolating from the EPA Water Quality Criteria 10^{-5} levels, the average concentrations of several target organics in some Montebello Forebay wells become close to an "actionable" level. If additional pharmacokinetic data are incorporated by the DOHS risk assessment guidelines, none of the drinking water levels may be "actionable". Under the DOHS policy, "actionable levels" appears to translate to the use of the theoretical models and assessment data as a "trigger" level which will cause detailed exposure assessment and risk characterization (steps 3 and 4) for an International Agency for Research on Cancer or National Cancer Institute carcinogen of concern in the specified environmental setting (e.g., air, water, workplace, food, etc.). The subsequent recommendation for regulation of sources of given substances would thus be based on this ultimate risk characterization. In the Montebello Forebay, management of "actionable levels" of chemicals in groundwater (if any indeed are determined to exist) should rely on guidelines which have included an evaluation of the data base for such chemicals in the groundwaters, an estimate of the extent of population exposure, evaluation of available epidemiology, characterization of replenishment sources, estimation of relative benefits from alternative control measures, and possibly, evaluation of the economic effects of regulation.

The foregoing discussion of possible health significance was presented in a framework of current state and federal agency approaches to risk assessment and possible risk management steps. These, in turn, rely on identification of specific compounds known to be carcinogens in mammalian species. However, a body of information presented earlier in this report showed the presence of very low concentrations of compounds with unknown identity in groundwater and surface waters, but which had functional chemical groups similar to known animal carcinogens, and which were implicated in genotoxic action (namely, mutagenicity in Ames' Salmonella microsome mutagen assay). While these data are suggestive, at the scientific research level, that further study is warranted in order to isolate and identify specific compounds and determine if their sources (including reclaimed water) actually present a health risk, the information cannot be used for a human risk assessment. The initial step, hazard identification, falls short for the following reasons:

(i) as a "substance", groundwater in the study area containing the unknown materials and some reclaimed water could not be linked to any adverse health effects by epidemiologic methods (see Chapter VII).

(ii) Positive response from in vitro assays and chemical similarity to suspect compounds are not considered sufficient evidence of carcinogenicity because of their inherent limitations. Actual chemical identification and in vivo animal testing is required.

The second step, dose-response assessment, is clearly impossible due to lack of chemical identification and subsequent lack of valid animal bioassays. Hence, mutagenicity data alone cannot be used to establish human risk.

SUMMARY AND CONCLUSIONS

Examination of the general organic nature of various surface and groundwater sources revealed that the range of molecular complexity and organic content followed the approximate order: surface runoff ≥ reclaimed water > imported water > groundwater. Further, it was observed that contamination of surface and groundwaters appeared to decrease according to distance from highly populated and industrialized centers.

Surveys of samples from all four study areas for target organics of known health significance showed that impacts on groundwater from different percolation sources could be detected, especially for chlorinated solvents. For example, storm waters and reclaimed waters appear to be significant sources of tetrachloroethylene in Montebello Forebay wells, while reclaimed water and Colorado River water may be significant contributors of trihalomethanes. In addition, a significant non-percolation source of the more toxic brominated trihalomethanes was attributed to well water disinfection practices. In contrast to the consistent presence of many of the volatile organic solvents, most nonpurgeable target organics were only sporadically found or not detected at all. However, phthalates appeared to be ubiquitous, although no predominate source could be identified. The herbicides atrazine and simazine were consistently present in groundwater, and were attributed entirely to surface application and runoff.

Although target organics present in different percolation sources can be detected in groundwater, the health impact of the levels observed appeared to be insignificant relative to EPA's maximum contaminant levels, California Department of Health Services "action levels" and National Academy of Sciences "suggested no adverse response levels." For those organics covered by the EPA Water Quality Criteria for lifetime cancer risk and for which the analytical detection limits of the procedures used were sufficient, average groundwater concentrations were below theoretical risk levels calculated from animal test data. These findings indicate that existing planned groundwater replenishment programs in the Montebello Forebay and Talbert Gap areas are not adversely impacting the groundwaters when viewed in terms of various agency limits or risk assessment guidelines for specific health significant compounds. Although this is a significant finding, toxicologists advise caution in interpretation of results when several toxic compounds exist together in a water supply, since their presence together may pose an increased risk that cannot be estimated by current models and methods.

Surveys of organic residues isolated from 90 samples for the presence of mutagenic organics (potential carcinogens) revealed mutagenic activity in at least one sample from each source. The level of activity or potency detected in various sample types followed the order: storm runoff > dry weather runoff > reclaimed water > groundwater > imported water. In more than half of the instances observed, chlorination led to an apparent formation of mutagens. In the Montebello Forebay, no simple correlation was observed between percent reclaimed water in wells and the observed mutagenic potency of residues isolated from the wells.

The pattern of mutagenicity in the bioassay of all samples was suggestive of direct-acting alkylating agents (no mammalian enzyme activation required). Altnough fractionation greatly simplified mutagenic residues and facilitated identification of many organics by electron ionization GC/MS, few mutagens were identified with these methods. Of the four known mutagens identified in six of the 33 samples evaluated in detail, none were present at levels that contributed significantly to the observed mutagenicity and none contained halogens.

Further characterization of mutagenic residues indicated the presence of basic, acidic, and neutral organic mutagens having relatively low molecular weight. Although not identified, several components were observed by GC/MS which might have contributed to the mutagenic activity observed in a few samples. Additional compounds were identified which, although not mutagens, belonged to classes of toxic organics. The latter included pesticides, plasticizers, and miscellaneous industrial compounds. Experiments were conducted to determine if some organics not amenable to GC/MS analysis were contributing to mutagenicity; however, the results could not absolutely rule out the possibility that higher molecular weight or thermally unstable toxic agents were involved.

Experiments with chemical derivatization, mutagen assay, and negative chemical ionization (NCI) GC/MS yielded results which were consistent with the presence of a multitude of mutagenic labile organohalides in well water, reclaimed water, surface runoff, and imported Colorado River water samples. The very low levels of individual compounds detected by NCI and the level of mutagenicity associated with their presence suggested that some of these may be potent mutagens containing chlorine, bromine, iodine, epoxide-oxygen, or a combination of these functional atoms. Although NCI spectra are insufficient for molecular structure assignments, several major components in this group were detected in both percolation sources and groundwaters. Possible sources of these materials include water chlorination as practiced in the industrial, drinking, and reclaimed water fields or biological production through enzyme mediation. The organohalides detected in groundwaters were not found to be unique to one replenishment source.

In light of the results of studies described in this chapter, there is little concrete evidence to suggest that an imminent health hazard exists from current groundwater replenishment practices in the Montebello Forebay. The results do, however, suggest the necessity for vigilance in the area of source management and control of some industrial organics. Virtually every location sampled showed the presence of common refractory industrial organic chemicals or halogenated organics from water chlorination processes. This fact suggests that all water supplies, whether destined for planned or unplanned reuse, are susceptible to and need protection from improper handling of chemicals. Obvious areas of emphasis include more stringent surveillance on disposal of industrial byproducts and wastes, and further evaluation of alternatives to use of chlorine for drinking wter disinfection and some industrial processes.

With regard to the widespread presence of mutagenicity in groundwater and surface water and the prolifity of apparently mutagenic organohalides (and possibly epoxides) in groundwater and percolation sources, it is deemed prudent to further characterize the molecular nature and specific biological effects of these components and to determine their probable sources. Such work will be necessary in order to confirm or refute the possibility that these agents pose a health hazard, and to provide a sound basis for recommendations for their control if necessary.

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CHAPTER V

PERCOLATION STUDY

INTRODUCTION

The final opportunity for the treatment of replenishment waters prior to their entrance into groundwater aquifers occurs in the soil strata through which the replenishment waters percolate. The soil solid phase functions as the site for physical and biological processes which directly influence the mobility of contaminants introduced into the soil system. The efficiency of these processes defines the soil's ability to attenuate any impact that replenishment waters may have on groundwater supplies. Accordingly, a field study was undertaken in an effort to quantify the effect of high-rate percolation on constituents typically found in water reclamation plant effluent.

There is a substantial body of literature regarding the removal of gross organics and inorganic nutrients and metals in land treatment systems. No attempt will be made to summarize such material in this work. However, significantly less research has addressed the mobility of trace organic compounds in soil systems. This research has developed only recently as a result of vastly improved analytical methodology for the identification and quantification of extremely small concentrations of organic compounds.

The available literature pertaining to the transport and fate of organic compounds identifies adsorption, volatilization and biodegradation as the primary factors which can influence contaminant mobility. Tomson et al. (V-1) undertook a field study at a 40 acre rapid infiltration site in Phoenix, Arizona. Activated sludge effluent had been spread at the site for seven years prior to the study. Although no spreading period was mentioned, it was stated that a drying period of 21 days was incorporated into the site operation. The authors identified 67 organic compounds in the effluent applied to the infiltration site. Samples drawn from 60 feet below the center of the spreading area indicated an overall removal efficiency of greater than 90 percent of the applied organics. The authors did not attempt to quantitatively determine the removal mechanism. However, it was presumptively stated that the importance of biodegradation was minimal and that adsorption and volatilization contributed substantially to contaminant removal. The effect of intermittent drying periods was not addressed.

Wilson et al. (V-2) applied a feed solution to borosilicate glass columns filled with 140 centimeters of fine sand. The feed solution consisted principally of halogenated hydrocarbons and substituted benzenes in concentrations ranging from approximately 0.2 mg/L to 1.0 mg/L. The columns were operated continuously under partially saturated conditions for 45 days. All compounds reached steady-state concentrations after 25 days indicating that the adsorptive capacity of the soil had been exhausted. Data indicated that approximately 46 percent of the halogenated hydrocarbons and 41 percent of the substituted benzenes remained in the effluent after percolation through the column. An effort was made to measure the percentage of applied organic compounds lost due to volatilization under laboratory conditions. Results indicated that volatilization was responsible for the removal of a substantial portion of the organic material from the feed solution.

Roberts et al. (V-3) modeled contaminant breakthrough curves based on the predicted effects of dispersion, adsorption and biodegradation, acting separately and concurrently in a semi-confined aquifer element. The breakthrough models were then utilized to interpret field data obtained at a groundwater injection facility located in the Palo Alto Baylands (California). Tertiary treated effluent was injected into a vertically confined aquifer and flowed radially outward to various monitoring wells. The fractional breakthrough of nine chlorinated and non-chlorinated organic compounds was observed at each monitoring location and compared to the injection water velocity as measured by a conservative tracer (chloride). The authors found breakthrough curves characteristic of adsorption and dispersion (without significant biodegradation) for chlorobenzene, styrene, benzonitrile and three dichlorobenzene isomers. The relative retention time (mean residence time of the contaminant divided by mean residence time of the injection water, t/t_{H_2O}) ranged from 36 (unitless) for chlorobenzene to greater than 200 (unitless) for the dichlorobenzene isomers. Naphthalene was found to display a concentration response characteristic of adsorption and biodegradation.

The processes affecting the transport and fate of organic compounds in the subsurface environment were examined by McCarty et al. (V-4). The authors developed a relationship between the relative retention time of a compound (adsorptive retardation) and its octanol/water partition coefficient. The calculated retention times compared favorably with the measured values obtained from field injection experiments as reported by Roberts et al. (V-3). The authors also performed small-scale column studies which indicated that for a single substrate there was a minimum concentration below which a steady-state biofilm could not be supported. It was hypothesized by both McCarty et al. (V-4) and Boethling and Alexander (V-5) that substrate concentrations below the minimum level were incapable of providing sufficient energy to maintain an active microbial population. However, the presence of a mixture of organic materials could lead to the development of a thicker biofilm layer which could degrade the trace organic material even though it was not the primary source of energy maintaining the microbial population. In this case, secondary utilization of the organic contaminant would lead to a minimum concentration well below that predicted in a single substrate system.

Roberts et al. (V-6) conducted a field study at the Palo Alto Baylands groundwater replenishment site in which it was found that the adsorptive retardation of trihalomethane compounds allowed for their eventual biodegradation. Tertiary effluent was injected into a vertically confined aquifer until observations at monitoring wells indicated that the adsorptive capacity of the aquifer had been saturated. Continued monitoring after injection had ceased indicated a substantial reduction in the concentration of trihalomethanes. For example, chloroform was reduced from an initial concentration of approximately 20 μg/L to a lower limit of 0.75 μg/L within 150 days. The authors ruled out sorption or dilution as possible explanations and concluded that the first order decline in trihalomethane concentration was the result of biodegradation.

Groundwater recharge in the Montebello Forebay was examined by McMichael and McKee (V-7). Although no specific trace organic compounds were analyzed, two test basins were constructed and operated to determine the effect of intermittent spreading on the quality of percolating effluent. Much of the design and operation of the test basin study presented in this chapter was derived from information provided by the McMichael and McKee report.

Test Basin Facilities

A field study was established to determine the water quality changes which occur during the percolation of reclaimed water through an undisturbed soil profile. It was initially hoped that the test basin site could be located in the confines of the existing spreading grounds so that the field study would directly reflect the physical site conditions of full-scale groundwater replenishment in the Montebello Forebay. However, this proved unsatisfactory as there was no practical means for segregating replenishment water supplies. The original Whittier Narrows test basin, constructed by the Los Angeles County Flood Control District (V-7), was deemed unsuitable due to the soil disturbance resulting from the extensive excavation which had accompanied the installation of the pan-type samplers.

A new test basin was eventually constructed north of the Whittier Narrows Dam directly adjacent to the original test basin as shown in Figure V-1. This site was chosen primarily due to the readily available access to undiluted Whittier Narrows Water Reclamation Plant (WRP) effluent.

The test basin was constructed so as to not disturb the original soil profile. Earthen berms, installed by the Los Angeles County Flood Control District (LACFCD), created a spreading area of approximately 3000 square feet (45 ft. x 67 ft.). Natural vegetation was allowed to grow in the basin but was periodically cut back to facilitate sampling.

Soil conditions at the site can be roughly characterized as medium to fine brown oxidized sand for the initial eight feet of depth with medium to coarse gray sand encountered at depths greater than 8 feet. The groundwater table was located at a depth of approximately 8 feet. A soil profile and associated physical and chemical parameters are provided in Tables M-1 and M-2 of Appendix M. It is important to note that soil characteristics at the test basin site differ significantly from that found at the Rio Hondo or San Gabriel River spreading grounds. Most notably, the test basin soil exhibited a significantly higher organic content, less homogeneity in terms of soil constituents and particle size, and a smaller average particle size.

In order to minimize soil disturbance during installation of the sampling units it was determined that in-situ tube-type samplers would be utilized. Due to anticipated sampling of volatile organic compounds it was necessary to ensure that the sampler assembly and/or the sample collection methodology would not interfere with the quantification of the organic compounds.

It was initially proposed that the sampler assembly consist of a Teflon tube body with a two inch diameter ceramic permeation cup attached to the bottom. The soil water would be drawn through the ceramic cup by applying a vacuum to

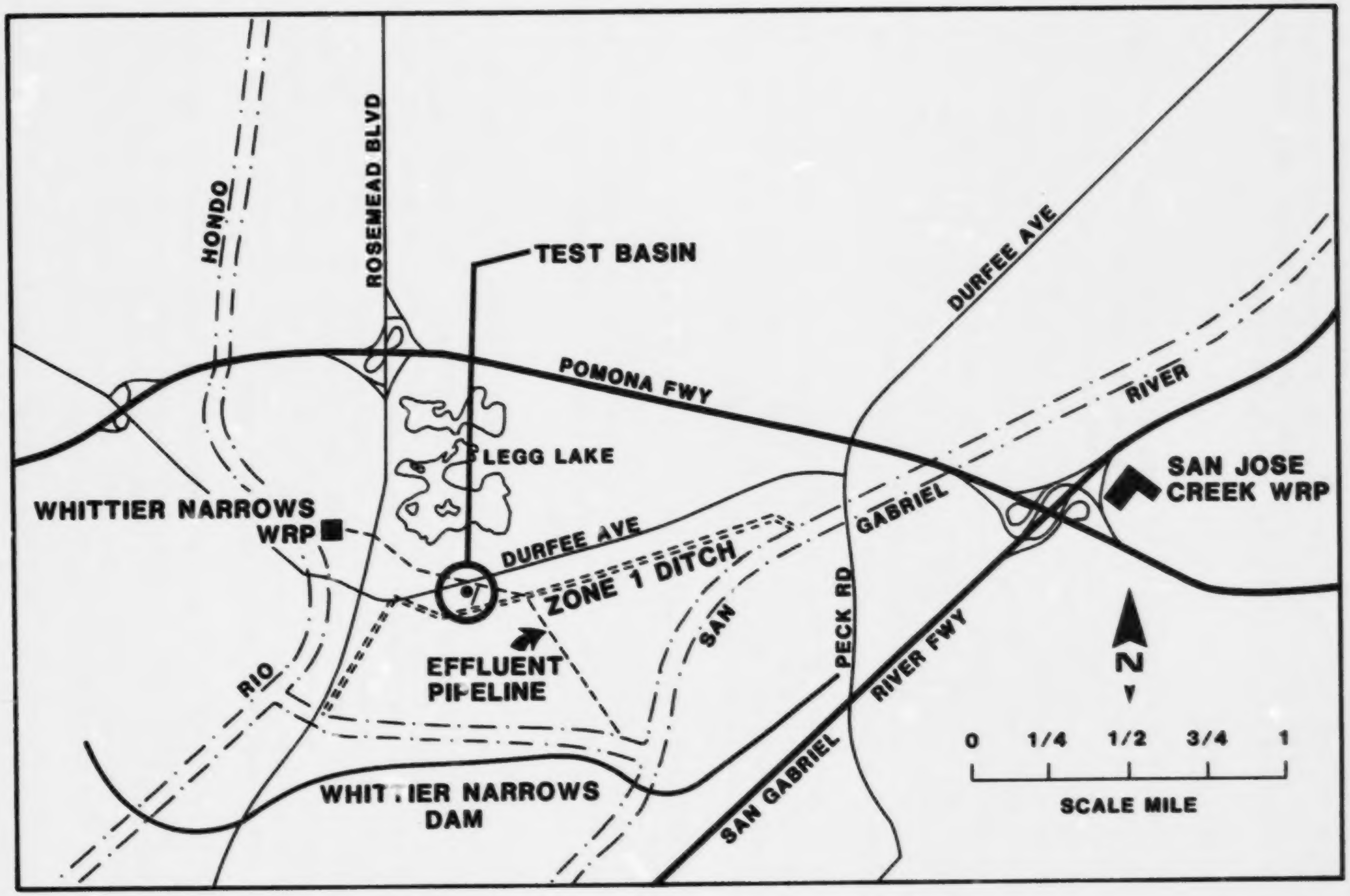

FIGURE V-1 LOCATION OF WHITTIER NARROWS TEST BASIN

the assembly with a small pump. The primary concerns with such an arrangement were that volatile organics might be lost during the vacuum procedure and that the ceramic cup might adsorb trace organic compounds. A series of tests were performed in order to investigate these concerns.

To determine if there would be any loss of volatile organic compounds during the proposed sampling process an aqueous standard solution containing methylene chloride, chloroform, trichloroethylene, and tetrachloroethylene at concentrations of 10 μg/L was prepared. The ceramic cup assembly was then submerged in a 450 mL beaker filled with the standard solution and a vacuum was applied. When a sufficient volume of solution had been drawn through the suction cup a portion (50 mL) was purged, trapped, desorbed, and analyzed by gas chromatography. An equal volume of the standard solution which was not drawn through the cup was analyzed in the same manner. The results indicated a loss of greater than 90 percent of each of the volatile organic compounds in the collection process.

In order to determine the mechanism by which the organic compounds were removed from the standard solution, a resin trap (Tenax GC - 60/80 mesh, Applied Science, Inc.) was installed in the vacuum line to collect the organic compounds which may have volatilized as the vacuum was applied to the suction cup. The above procedure was repeated, the trap was desorbed, and the volatile organic concentration was analyzed by gas chromatography. The resultant chromatogram indicated that volatilization was not the primary removal mechanism.

Thus, it seemed likely that the loss of volatile organic matter in the proposed sampling process was primarily due to adsorption by the porous ceramic cup. In order to verify this explanation, the previously utilized ceramic cup was immersed in a five percent methanol-water solution. A vacuum was applied, the solution was drawn through the cup and a 50 mL aliquot sample was purged, trapped, and analyzed. The high concentration of volatile organics observed indicated very substantial adsorption of volatile organics by the ceramic cup. Consequently, an alternative sampler assembly was devised.

The selected sampler assembly consisted entirely of stainless steel and Teflon materials. As shown in Figure V-2, a 200 mesh stainless steel screen was clamped over the open end of a 3 inch diameter stainless steel cylinder. A pair of 0.25 inch diameter Teflon tubes entered the closed end of the assembly through welded Swagelok® fittings. One of the Teflon tubes extended to the bottom of the sampler and was used to draw samples from within the assembly. The other tube extended only a short distance into the assembly and provided an open connection between the interior of the assembly and the atmosphere.

The substitution of the 200 mesh stainless steel screen for the ceramic cup was prompted by the determination that the ceramic cup interfered with volatile organics sampling. The stainless steel screen was tested in laboratory sand column experiments and was judged more suitable in that (a) there was no appreciable adsorption of organic compounds by the screen and, (b) the greater permeability of the screen eliminated the need to apply a vacuum to the cylinder thus alleviating any concerns regarding volatilization of organic compounds during this process.

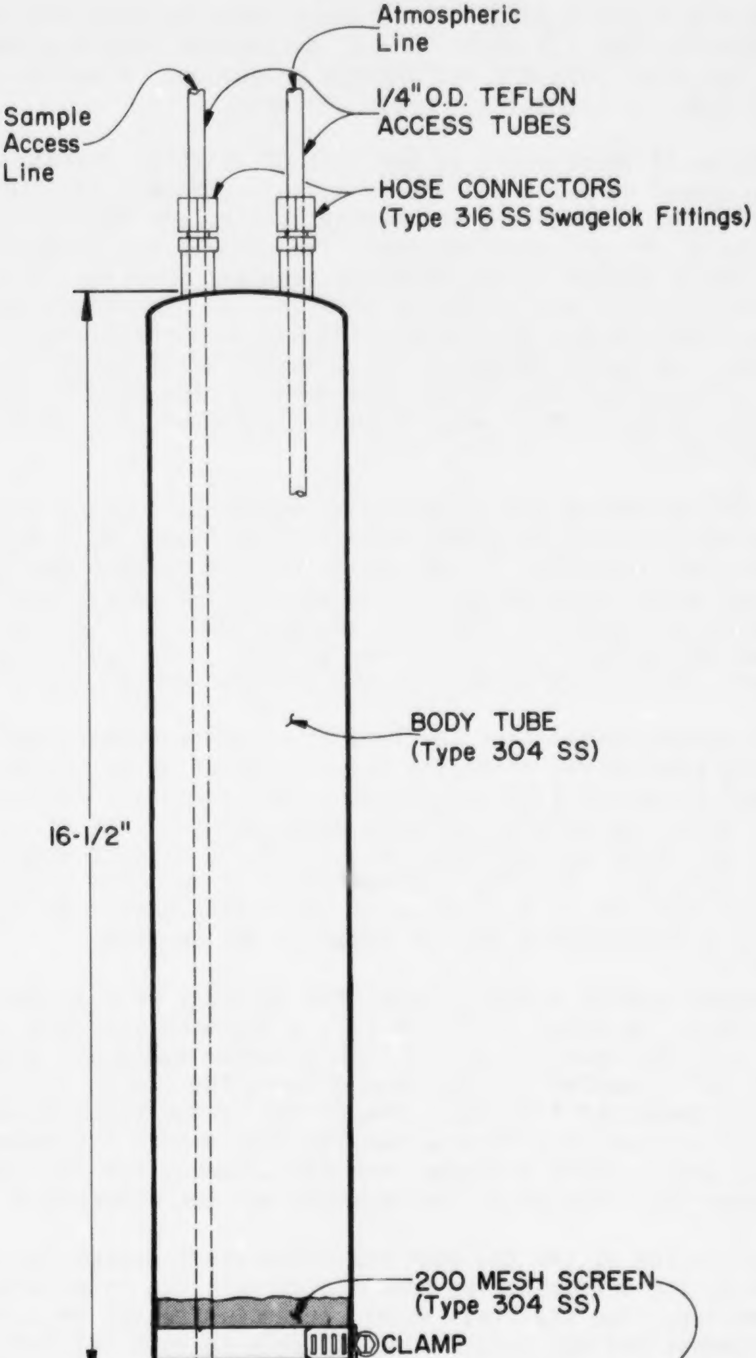
Atmospheric Line
Sample Access Line
1/4" O.D. TEFLON ACCESS TUBES
HOSE CONNECTORS (Type 316 SS Swagelok Fittings)
BODY TUBE (Type 304 SS)
16-1/2"
200 MESH SCREEN (Type 304 SS)
CLAMP
2-3/4" I.D.

FIGURE V-2 GROUNDWATER SAMPLER FOR WHITTIER NARROWS PERCOLATION STUDY

The sample access tube extended from the in-situ sampler unit to the sampling station located at the edge of the test basin. Samples were drawn from the sampling units with a stainless steel/teflon, variable speed, magnetic drive gear pump. A hand-operated vacuum pump was used to prime the electric gear pump.

A total of twelve sampler units were installed in the test basin: three each at depths of 2, 4, and 6 feet, one at 7 feet, and two at 8 feet. The samplers were placed in three rows evenly distributed across the basin with the sampler depth randomly varied in each row (see Figure V-3). Bores at depths of up to 6 feet were drilled using a 5½ inch diameter gas powered auger. A 4 inch diameter hand auger was used to complete the drilling for the 7 and 8 foot holes.

The installation of the sampler units consisted of a) placing 1 inch of clean sand at the bottom of each bore, b) lowering the sampler into the bore, c) backfilling the bore to a level approximately 2 feet below the surface, d) placing a bentonite plug at the 2 foot depth to prevent short circuiting of the percolate through the disturbed soil column, and e) backfilling the bore to the surface elevation. In order to minimize project disruption due to vandalism, stainless steel Swagelok® connectors were installed in each Teflon tube approximately 6 inches below the soil surface. It was hoped that this precaution would insure that any sub-surface disconnection of the tubing would occur at the shallow connectors rather than at the sampler unit.

Test Basin Operation

The source of reclaimed water for the percolation study was the Whittier Narrows Water Reclamation Plant (ref. Chapter III). Typically, this effluent passes the test basin site on its way to the Rio Hondo spreading grounds. However, previously constructed turnout facilities were capable of diverting a portion of the flow to the test basin site. That which was not utilized at the test basin was bypassed to the Zone I Ditch where it rejoined the effluent flowing to the spreading grounds. Reclaimed water flowed into the test basin over a fixed elevation wooden V-notch weir. Consequently, the rate of flow to the basin was dependent upon the depth of water in the weir forebay which in turn was dependent upon the rate that reclaimed water was diverted from the Whittier Narrows WRP effluent pipeline.

The flooding and drying schedule for the test basin was originally planned to simulate the seven day flooding/14 day drying period employed at the spreading grounds. However, at the request of the Los Angeles County Flood Control District, this schedule was modified to better suit the availability of LACFCD personnel who were responsible for flow diversion to the site. The revised schedule consisted of five days of flooding followed by 16 days of drying.

The selection of constituents to be monitored for the test basin study was based on each constituent's environmental significance and/or characteristic ability to indicate the prevailing soil environment or specific soil activity. In addition, it was necessary that monitored constituents be consistently present in Whittier Narrows Water Reclamation Plant effluent. For this reason, only four trace organic compounds were monitored: methylene chloride, chloro-

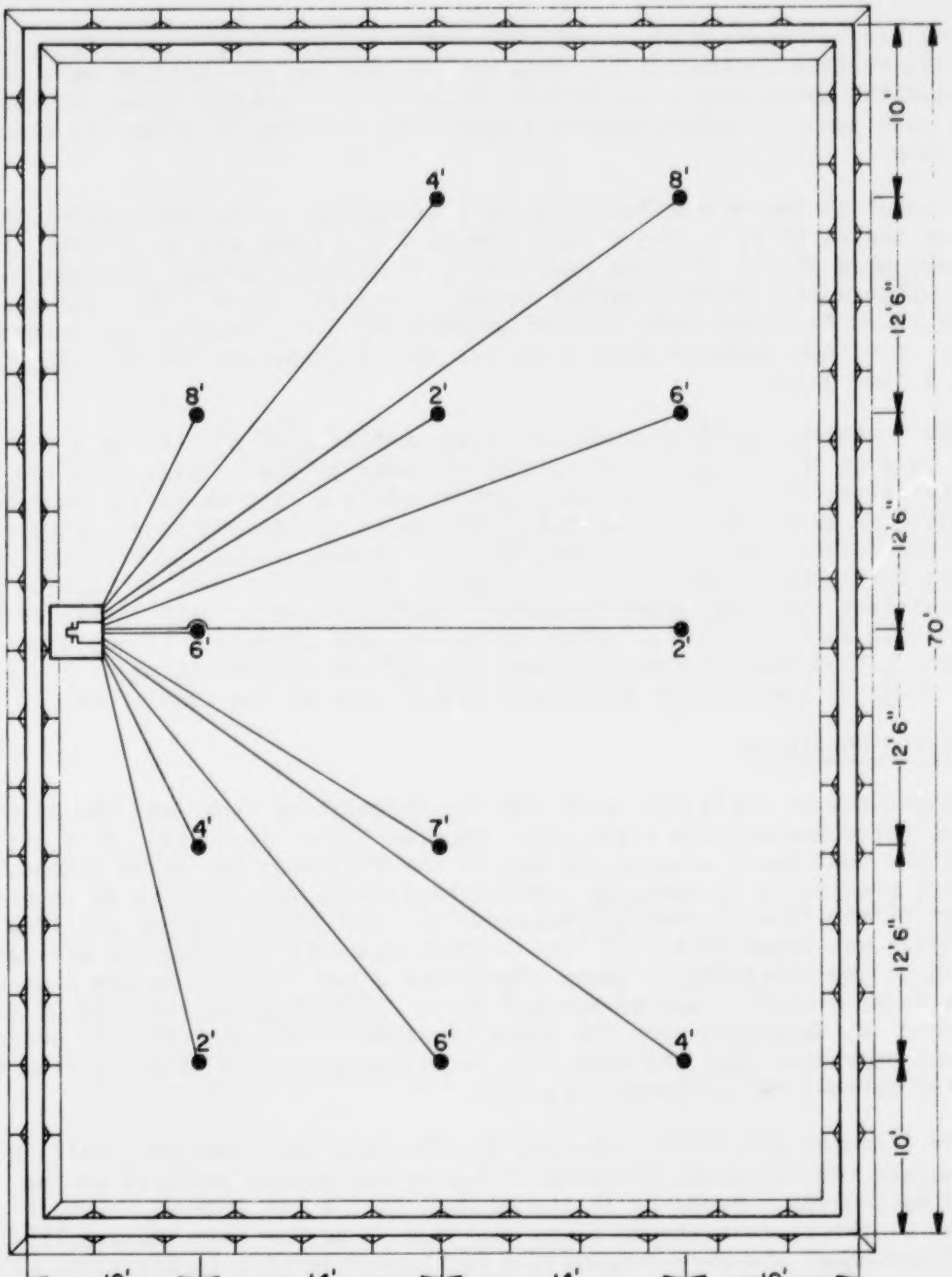

FIGURE V-3 LOCATION OF SAMPLERS AT THE WHITTIER NARROWS TEST BASIN

form, trichloroethylene, and tetrachloroethylene. Table V-1 lists all constituents routinely analyzed during the percolation study.

TABLE V-1

CONSTITUENTS MONITORED DURING PERCOLATION STUDY

Methylene Chloride (CH_2Cl_2)	Ammonia Nitrogen (NH_3-N)
Chloroform ($CHCl_3$)	Nitrite Nitrogen (NO_2-N)
Trichloroethylene (C_2HCl_3)	Nitrate Nitrogen (NO_3-N)
Tetrachloroethylene (C_2HCl_4)	Total Dissolved Solids (TDS)
Chemical Oxygen Demand (COD)	Total Hardness (as $CaCO_3$)
Total Organic Carbon (TOC)	

Laboratory methodology for the examination of each constituent is discussed in Chapter III (inorganics) and Chapter IV (organics).

Test basin sampling was conducted on the third day of each flooding cycle. Each sampler was first evacuated so that a fresh sample could be obtained. The samples usually refilled in 20 to 30 minutes. The percolate sample was then drawn and deposited in two containers. For trace organic analyses, a 40 mL screw top septum vial was filled and carefully capped with a Teflon/silicone disc to ensure that no headspace or bubbles were present. The remainder of each sample was then placed in a one liter Nalgene bottle to be used for inorganic and gross organic analyses. Influent samples were collected by hand at the V-notch influent weir.

RESULTS AND CONCLUSIONS

Basin Operation

The test basin was initially flooded in June 1980. Four complete flooding/drying cycles were conducted in the following three months to condition the basin and develop sampling methodology. The limited data obtained during this period were not included in the results presented herein.

The initial flooding cycle indicated that the hard-packed basin surface was relatively impervious. Consequently, the infiltration rate was insufficient to saturate the upper 4 to 5 feet of soil. In order to increase the permeability of the basin surface, a rototiller was used to cultivate the top 5 inches of soil. The infiltration rate improved substantially, ultimately reaching an average of 2.5 to 3.0 feet/day during the actual study. The resultant saturated conditions enabled samples to be drawn from all depths.

During the conditioning period, it was noted that several sampling units were operating incorrectly. Fortunately, repairs could be made at the surface with the exception of the sampler buried at a depth of 7 feet. Since its repair would require substantial disruption of the soil, the 7-foot sampler was abandoned.

Full scale basin sampling began in September 1980 and concluded in July 1981.

Data Analysis

During the course of the percolation study, the basin was subjected to 15 flooding/drying cycles, of which seven were monitored. This resulted in approximately 500 chemical analyses which were grouped in terms of sample depth, disregarding the horizontal location within the basin. In this manner, a single soil profile was developed for each constituent.

All data sets were subjected to Chauvenet's criterion for the rejection of outliers (V-8). This resulted in the rejection of less than four percent of the data collected.

Inorganics and Gross Organics. Concentration/depth profiles for the inorganic and gross organic parameters monitored at the test basin are presented in Figures V-4 and V-5. A tabular summary of the collected data is presented in Table V-2.

The inorganic and gross organic parameters monitored in this study were selected in order to (a) show the effect of percolation on constituents of environmental and/or health concern and (b) to indicate general soil operating conditions.

The most apparent trend to be discerned from the concentration/depth profiles shown in Figures V-4 and V-5 was the elevated activity which occurred between the 4 foot and 6 foot monitoring depths. This activity was particularly evident in the profiles for chemical oxygen demand (COD), total dissolved solids (TDS), total hardness, and nitrate-nitrogen.

The rapid increase in the concentration of nitrate-nitrogen between the 4 and 6 foot depths coupled with the concurrent decrease in the concentration of ammonia-nitrogen is a clear indication that nitrification occurred at this depth. The nitrification of ammonia to nitrate is an oxygen-intensive autotrophic biological process. Consequently, it can be concluded that aerobic conditions existed to a depth of at least 4 feet.

A mass balance of the inorganic nitrogen species indicates a net loss of nitrogen within the test basin. The unaccounted-for nitrogen may have been incorporated into the active microbial population, incorporated into the surface vegetation, volatilized, denitrified, or fixed to clay and/or organic matter. The specific mechanism (or mechanisms) is unknown. However, only volatilization and denitrification could remove nitrogen from the system on a long-term basis. Extensive denitrification is unlikely as it is an anaerobic biological process requiring a substantial source of accessible energy in the form of organic carbon. Insufficient organic carbon was available for this process. Similarly, the absence of a reduction in the concentration of ammonia-nitrogen in the initial 2 foot layer of soil indicated that volatilization was not a significant nitrogen removal mechanism. Accordingly, it is expected that, were operation of the test basin to continue, the nitrate-nitrogen concentration at the 8 foot depth would increase to a level comparable to the influent ammonia-nitrogen concentration.

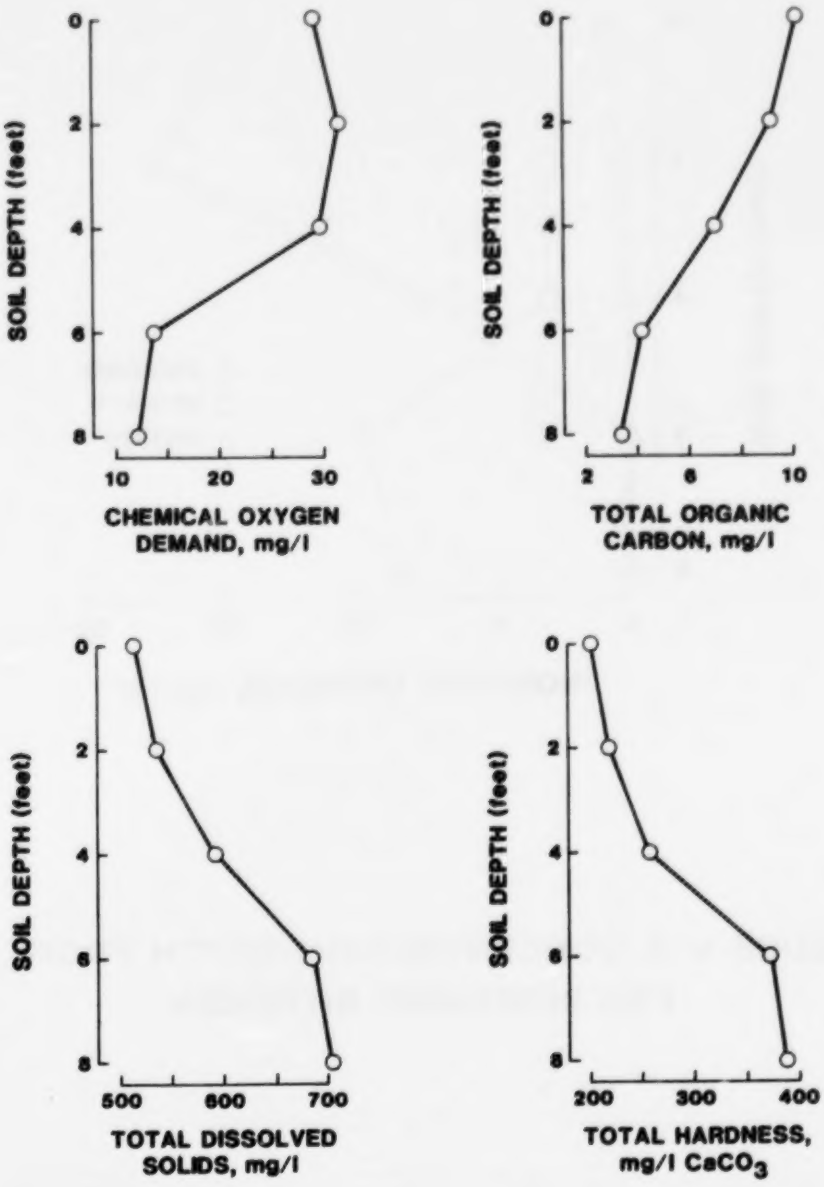

FIGURE V-4 CONCENTRATION/DEPTH PROFILES FOR INORGANIC AND GROSS ORGANIC PARAMETERS

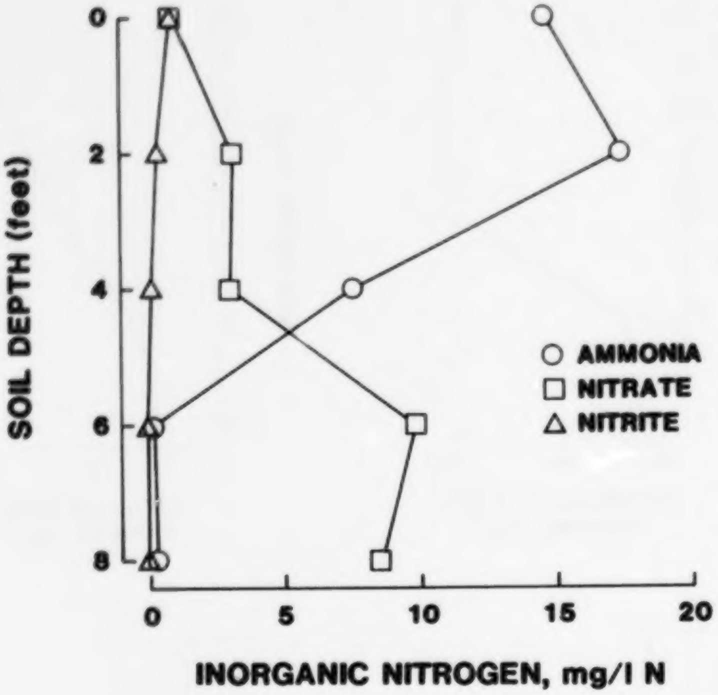

FIGURE V-5 CONCENTRATION/DEPTH PROFILE
FOR INORGANIC NITROGEN

TABLE V-2

AVERAGE CONCENTRATION OF INORGANICS AND GROSS ORGANICS AT WHITTIER NARROWS TEST BASIN

Constituent	Concentration				
		Soil Depth (feet)			
	Influent	2	4	6	8
Total Organic Carbon, mg/L	10.15	9.19	7.04	4.26	3.43
Chemical Oxygen Demand, mg/L	29.3	30.6	29.7	13.8	12.3
Total Hardness, mg/L $CaCO_3$	202	220	257	351	373
Total Dissolved Solids, mg/L	516	568	592	684	703
Ammonia, mg/L N	14.6	17.4	7.5	0.18	0.25
Nitrate, mg/L N	0.91	3.14	3.02	9.79	8.52
Nitrite, mg/L N	0.86	0.31	0.14	0.01	0.02

The COD concentration/depth profile shows a substantial reduction in concentration between the 4 and 6 foot depths. This is deemed to be the result of aerobic biological activity. The concurrent reduction in total organic carbon supports this conclusion.

The concentration of both total dissolved solids and total hardness increased substantially between the 4 and 6 foot depths. This suggests that there may be some relationship between the reported biological activity and the dissolution of soil solids. McMichael and McKee (V-7) hypothesized that the pH reduction which would accompany both nitrification and the biodegradation of carbonaceous substances could aid in the dissolution of calcium carbonate or iron minerals found in the soil matrix. This hypothesis was based on a similar study in which it was observed that the majority of the microbial activity and the majority of the dissolution of minerals occurred concurrently in the upper 2 feet of soil. The fact that the microbial activity reported herein occurred predominantly in the layer of soil between the 4 foot and the 6 foot samples and was also accompanied by a sharp increase in TDS and hardness serves to further support this hypothesis. It should be noted, however, that McMichael and McKee (V-7) also found very little increase in dissolved solids in percolate taken from a spreading basin that had been in operation for eight years. Presumably, the dissolution rate slowed considerably after the more easily dissolved minerals were leached from the soil.

The above discussion brings to light an unexplained result of the study. The primary test basin utilized in the McMichael and McKee study (V-7) was located directly adjacent to the basin constructed for this study. However, the biologically active soil layer in each basin was located at different depths. The McMichael and McKee basin displayed significant biodegradation and nitrification in the top 2 feet of soil whereas this study did not detect similar activity until the reclaimed water had percolated to a depth of 4 to 6 feet.

The most significant difference between the two basins was the method of construction. The original soil profile in the McMichael and McKee basin was disrupted during installation of the sampling units. On the other hand, construction of the new basin was specifically conducted with the intent of minimizing such disruption.

Although not visibly detected, it is possible that deep surface cracks extended through the top 2 to 4 feet of the hard-packed natural soil strata. This could lead to "short-circuiting" of the majority of the percolated water through the largest cracks. As a result, biological activity would not be significant until the percolating water reached a more uniformly permeable layer of soil and spread into the small soil pore spaces. This would explain the "delayed" activity exhibited in the concentration/depth profiles. This effect would not be expected in a loose sandy soil such as that found at the full-scale spreading grounds located in the Montebello Forebay.

Trace Organics. Concentration/depth profiles for the four volatile organic compounds monitored at the test basin are presented in Figure V-6. A tabular representation of the data is presented in Table V-3.

Methylene chloride displayed the most substantial concentration reduction during percolation through the soil. The average influent concentration (16.9

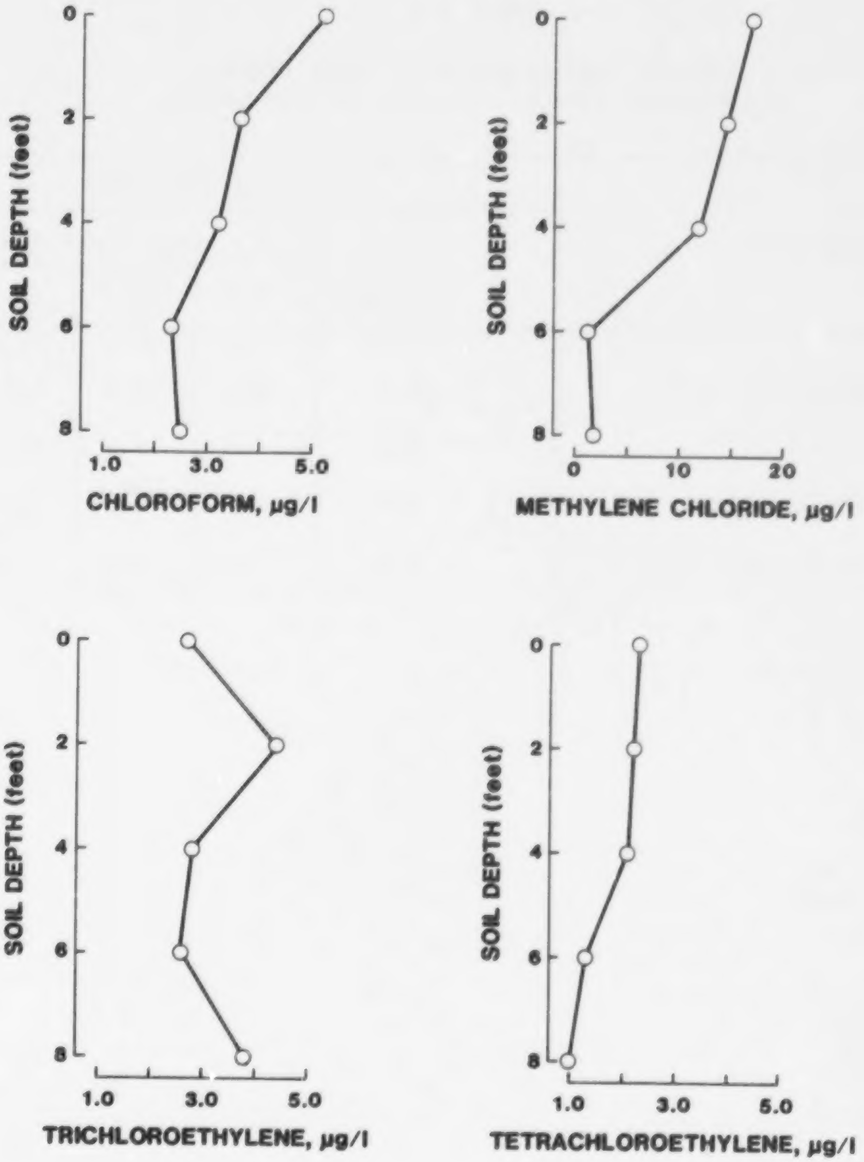

FIGURE V-6 CONCENTRATION/DEPTH PROFILES FOR TRACE ORGANIC COMPOUNDS

TABLE V-3

AVERAGE CONCENTRATION OF TRACE ORGANIC COMPOUNDS AT WHITTIER NARROWS TEST BASIN

Constituent	Concentration				
		Soil Depth (feet)			
	Influent	2	4	6	8
Methylene Chloride, μg/L	16.9	14.3	11.8	1.3	1.9
Chloroform, μg/L	5.2	3.6	3.2	2.3	2.5
Trichloroethylene, μg/L	2.7	4.4	2.8	2.6	3.8
Tetrachloroethylene, μg/L	2.3	2.2	2.1	1.3	1.0

μg/L) was reduced almost 90 percent to an average of 1.9 μg/L at a depth of 8 feet. Chloroform and tetrachloroethylene showed less dramatic but statistically significant (at a two percent level of significance) removals of 52 percent and 56 percent, respectively. However, the concentration of trichloroethylene was not reduced during percolation through the first 8 feet of soil. In fact, the statistical variance of the tricholoroethylene data obtained at each depth did not decrease with depth. In other words, while fluctuations in the influent concentration of the other three trace organic compounds were dampened during percolation through the soil, trichloroethylene showed no such trend. Consequently, the tricholoroethylene concentration calculated for each depth is an average of a wide range of data points. This results in a less precise average and explains the "zig-zag" effect displayed by the tricholoroethylene concentration/depth profile.

There are three mechanisms which could significantly alter the concentration of the monitored organic compounds under the conditions of this study - adsorption, volatilization, and biodegradation. The long-term efficacy of soil treatment is dependent upon the nature of the operative treatment mechanism.

It should be noted that, in a steady-state system, the adsorptive capacity of a soil will become saturated in a finite period and subsequently provide no contaminant attenuation. However, since the test basin was subjected to limited use, it is necessary to first assume that its adsorptive capacity was not fully saturated during the sampling period. Consequently, it is important to estimate the impact of adsorption on each of the organic compounds monitored in the test basin.

It has been reported that, for small concentrations of organic compounds, there is an empirical correlation between the compound's octanol/water partition coefficient and its relative adsorptive affinity (V-1, V-4, V-9). McCarty et al. (V-4) compared calculated pollutant retention periods to field data and concluded that compounds with octanol/water partition coefficients less than 1000 (unitless) were able to move through the subsurface environment "quite readily." In contrast, Tomson et al. (V-1) stated that, for compounds with octanol/water partition coefficients greater than 175 (unitless), adsorption would be an "important mechanism" in the prevention of groundwater contamination. Both investigators utilized work published by Karickhoff et al. (V-9) to formulate an equation for the estimation of the relative retention time of a pollutant traveling through soils:

$$t_r = 1 + (0.63)(OC)\,\frac{p}{n}\,K_{ow}$$

where t_r = relative retention time (velocity of water/velocity of pollutant);
OC = soil organic fraction, percent;
p = bulk density of aquifer material, kg/m^3;
n = porosity of aquifer, percent;
and K_{ow} = octanol/water partition coefficient.

The contradictory conclusions reached by the above investigators are primarily the result of (a) different assumptions regarding aquifer characteristics (organic carbon content) and (b) different definitions of acceptable pollutant transport velocity. Organic carbon content is a characteristic specific to each soil and can be determined in the laboratory, while pollutant transport velocity is a subjective determination and can therefore vary significantly. For example, McCarty et al. (V-4) felt that a relative retention time of 58 (K_{OW} = 1000) indicated that the pollutant would be transported through an aquifer quite readily. On the other hand, Tomson et al. (V-1) felt that a relative retention time of 21 (K_{OW} = 175) was significant in terms of the prevention of groundwater contamination.

The application of this equation to the Whittier Narrows Test Basin can provide a general idea of the adsorptive affinity of each of the organic compounds monitored. As shown in Table V-4, it is predicted that all four compounds would saturate the top 8 feet of soil within 28 spreading days. In fact, based on an average of five spreading days per cycle, the capacity of the basin to adsorb methylene chloride, chloroform, and trichloroethylene should have been completely utilized during the basin conditioning process. Therefore, adsorption probably did not contribute significantly to the trace organic compound removal detected in the test basin.

A second mechanism often regarded as being very effective in the removal of certain organics from wastewater is volatilization. In a groundwater recharge operation, the greatest amount of volatilization would be expected to occur in the ponded effluent or within the first few inches of soil. Accordingly, volatilization would characteristically appear in Figure V-6 as a decrease in concentration between the zero-foot depth (basin influent) and the 2-foot depth. It would also be expected that, since volatilization would occur only in this region, its influence would result in a greater concentration reduction rate between the zero and 2 foot samples than between the 2 and 4 foot samples. This assumes that any concurrently operating removal mechanism acts consistently in the top 4 feet of soil - an assumption that is supported by the uniformity of the top 4 feet of soil (see Appendix M, Table M-1).

The data show no concrete evidence of volatilization. Only chloroform exhibits a concentration/depth profile that appears to conform to the characteristics that would indicate volatilization. The volatilization of chloroform would not be surprising in that it is highly volatile and, in part, formed as a product of chlorination and therefore not subjected to the turbulent aeration of the wastewater treatment process. However, the "excess" concentration reduction seen in the top 2 feet of the chloroform profile is not statistically significant and therefore conclusions can only be speculative. In any case, judging from the limited removals detected between the basin influent and the 2 foot depth, volatilization did not appear to be a significant treatment mechanism during effluent percolation.

The third and final mechanism which could significantly contribute to the treatment of trace organic compounds in soil percolation systems is biodegradation. There is some doubt as to the ability of a soil percolation system to further degrade compounds which, by their presence in an activated sludge effluent, have demonstrated a certain resistance to biological degradation. The activated sludge process includes approximately six hours of highly concentrated biological activity. On the other hand, it is estimated that the Whittier

TABLE V-4

PREDICTED ADSORPTIVE RETENTION OF SELECTED ORGANIC COMPOUNDS AT WHITTIER NARROWS TEST BASIN[a]

Compound	Octanol/Water Partition Coefficient, K_{ow}	Relative Retention Time, t_r (unitless)	Predicted Break-through at 8-foot Depth, days[b]
Methylene Chloride	18[c]	3	2
Chloroform	89[d]	11	7
Trichloroethylene	195[d]	22	13
Tetrachloroethylene	398[d]	45	28

[a] Estimated organic content = 2%; bulk density = 2 gm/cm^3; porosity = 0.23.

[b] Days of spreading predicted for complete breakthrough of compound at 8-foot depth assuming application rate of 3 feet/day.

[c] Reference V-10.

[d] Reference V-11.

Narrows Test Basin provided a hydraulic residence time of 15 to 20 hours within the top 8 feet of soil. Biological activity within the test basin would be much less intense - limited primarily by the lack of sufficient substrate. However, it appears that biodegradation, perhaps aided by the temporary retention of organics on adsorption sites, was the primary mechanism for the removal of the trace organic compounds.

The tentative conclusion that significant biodegradation of the monitored trace organics took place within the test basin is based upon three independent observations. First, there was virtually no removal of trichloroethylene within the top 8 feet of the test basin. Since trichloroethylene has a greater theoretical adsorptive affinity (i.e. higher octanol/water partition coefficient) than either methylene chloride or chloroform, yet displayed no adsorptive removal, it can be deduced that adsorption was not a significant removal mechanism for methylene chloride or chloroform. Similarly, since trichloroethylene has been shown to evaporate from water at approximately the same rate as chloroform and methylene chloride (V-2, V-8), yet displayed no evaporative removal, it can be concluded that volatilization was not a significant removal mechanism. Second, the concentration/depth profiles for inorganic nitrogen, chemical oxygen demand, and total organic carbon all indicate substantial biological activity. The occurrence of nitrification below the 4 foot depth indicates that aerobic conditions predominated at that level. Presumably, the soil environment was suitable for the aerobic biodegradation of trace organic compounds. Finally, a field study conducted by Roberts et al. (V-6) indicated substantial biodegradation of chloroform and other trihalomethanes in a confined aquifer. The concentration of the chloroform decreased at a rate approximately ten times that for trichloroethylene and tetrachloroethylene. Therefore, substantial biodegradation of chloroform could have occurred without significant biodegradation of trichloroethylene or tetrachloroethylene. The susceptibility of methylene chloride to biodegradation in the soil environment has not been documented to date. However, its low adsorptive affinity suggests that the nearly 90 percent reduction in methylene chloride concentration was the result of biodegradation.

The application of the results presented herein to full-scale groundwater replenishment operations must take into consideration the specific site conditions of both the test basin and the proposed spreading grounds. In particular, differences in soil properties and basin operation should be examined.

The physical and chemical properties of the soil in the test basin are somewhat different from the soil in the Rio Hondo and San Gabriel River spreading grounds. The spreading grounds generally have less organic content, greater porosity, and are highly weathered due to the intermittent flooding to which they are subjected. Consequently, these soils are likely to exhibit less adsorption capacity, have greater permeability, and be more resistant to erosion and dissolution. The net result would be a lower relative retention time (i.e. contaminants would be transported through the soil more quickly) and a less significant increase in TDS and total hardness concentrations than reported in this study.

Basin operation can also have an effect on the impact of replenishing groundwater aquifers with reclaimed water. In this study, undiluted reclaimed water was utilized. However, in the Montebello Forebay spreading grounds, historic use of reclaimed water has averaged only 16 percent of the total replenishment supply with an annual maximum of 23 percent. In other words, groundwater replenishment supplies have typically been utilized at a ratio of approximately four parts non-reclaimed water to one part reclaimed water. However, this ratio is limited by the volume of non-reclaimed water available and an interim agreement restricting the volume of reclaimed water which may be spread. The optimum dilution ratio would be based upon the mass contribution of one or more critical constituents to the groundwater system by each replenishment water supply after percolation through the soil strata. Accordingly, the quality of non-reclaimed water supplies (see Chapters III and IV) is as important as the quality of reclaimed water supplies in determining the impact of groundwater replenishment. Therefore, the development of criteria for the use of reclaimed water for groundwater replenishment must take into consideration the quality and quantity of all source waters to be used in the operation.

The utilization of an intermittent spreading/drying operation may significantly enhance the effectiveness of replenishment operations in terms of trace organic removal. Although no directly supportive data were developed during the study, it is reasonable to postulate that the two-week drying stage could increase the efficacy of biodegradation, volatilization, and adsorption. At the conclusion of the spreading cycle, the soil saturation front slowly retreats from the artificially elevated level to the original groundwater table. In the process, fresh air is drawn into the soil pore spaces and the soil moisture content is gradually reduced. During this period, conditions would be favorable for aerobic microorganisms to continue to biologically oxidize organic matter that has been adsorbed to soil particles. In addition, the evaporative drying of the soil could lead to the volatilization of adsorbed organic compounds. Should one or both of these processes act to "regenerate" adsorption sites, the effective adsorption capacity of the soil could be greatly increased. It is possible that an iterative cycle of adsorption followed by biodegradation and/or volatilization could substantially reduce the mass of trace organic compounds which enter the groundwater through intermittent surface replenishment operations. Further study pertaining to the operation of spreading basins and its effect on the removal of trace organic compounds is warranted.

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CHAPTER VI

DEVELOPMENT OF POPULATION EXPOSURE DATA

INTRODUCTION

Replenishment of local groundwater supplies using treated wastewater has been practiced in the Montebello Forebay area of Los Angeles County since 1962. As a result, residents in this area have been receiving varying percentages of reclaimed water in their domestic water supply depending on 1) the proportion of groundwater making up the total supply and 2) the amount of reclaimed water contained in the groundwater. One major task of the Health Effects Study has been directed towards identifying the proportion of reclaimed water contained in the total water supply. The procedures used to develop these population exposure data are described in this chapter.

ESTIMATION OF RECLAIMED WATER IN GROUNDWATER

Computer Models

During the earliest stages of the Health Effects Study, available methods for estimating percentages of reclaimed water contained in Montebello Forebay well waters were reviewed. One approach involved the use of computer techniques such as dispersion or finite element models. However, during subsequent evaluation of these models, several difficulties became apparent which precluded their use. The major problem was the lack of reliable input data on the physical and dynamic characteristics of the Montebello Forebay aquifer system. Essentially, no data existed on the extent to which newly percolated water mixed and co-mingled with native groundwater and to the extent to which a given well drew from different aquifers, or the proportions drawn from different sections of the same aquifer.

Wastewater Tracer

A second approach involved the use of a wastewater tracer which, when quantified in Montebello Forebay groundwaters, would provide an estimate of the proportion of reclaimed water reaching a given well. An investigation was conducted to identify a tracer that would be chemically conservative (i.e., not affected by percolation and not degraded over time), and would be uniquely associated with reclaimed water (negligible inputs from other sources).

The preliminary screening produced three potential tracer candidates: nitrate, bromide, and coprostanone. Subsequent evaluation demonstrated that each candidate was unsuitable for a variety of reasons. Nitrate proved to be unsuitable because of the significant impacts from fertilizer usage in the Montebello Forebay area prior to urban development in the 1950s. Bromide was ruled out as a tracer because its concentration in the groundwater was indistinguishable from that of reclaimed water. The last candidate, coprostanone also proved to be unsuitable. Coprostanone is the primary biological oxidation product of coprostanol, a characteristic sterol of human sewage which has been used as a tracer of sewage pollution (VI-1). However, attempts at isolating and quantifying coprostanol and coprostanone in reclaimed water and groundwater met with little success for a variety of analytical reasons. At this point, the wastewater tracer investigation was terminated.

Sulfate Model

The final approach considered for estimating the percentage of reclaimed water in Montebello Forebay groundwater was an empirical model which used sulfate as the tracer of groundwater movement. This approach had already been used during an earlier study of the Central and West Coast Basin groundwater system (VI-2) to define the relationship between water spread in the Montebello Forebay and water pumped from wells. The premise for the model was the differential between the sulfate concentration of Colorado River water, a replenishment source since 1954, and the sulfate concentrations of storm water, reclaimed water, and native groundwater; the concentration of Colorado River water was at least three times greater than the other source waters. Sulfate was considered to be a conservative material not likely to be affected by either vertical or horizontal movement through soil. As such, observations of the changes in sulfate concentrations in the wells over time paired with the historical proportions of replenishment waters spread each year, allowed for the movement of Colorado River water to be charted through the groundwater basin. Specifically, this approach arbitrarily divided the basin into 29 subareas and evaluated the sulfate data for wells within each subarea in terms of the percentage of Colorado River water replacing the native groundwater in a well over time. Curves for the individual wells were combined to form an idealized replacement curve for the entire subarea.

For the purpose of this project, it was decided to adopt an approach similar to the one above by simulating the movement of reclaimed water through the groundwater system with the movement of Colorado River water. Rather than using the rough approximations of Colorado River water replacement values obtained from the previously developed idealized hydrographs, new curves were developed for each Montebello Forebay well with sufficient water quality and hydrogeologic data. Sulfate data were applied to an empirical model to derive Colorado River water replacement values as follows:

$$R_C = \frac{1}{\alpha} \left[\frac{W_S - G_S}{C_S - G_S} \right] \times 100$$

where R_C = percent replacement by Colorado River water,
W_S = sulfate concentration of a well,
G_S = sulfate concentration of native groundwater,
C_S = sulfate concentration of Colorado River water,
and α = dilution factor.

To simplify the derivation of replacement values, the sulfate concentration of the native groundwater was assumed to be 30 mg/L while the sulfate concentration of Colorado River water was assumed to be 300 mg/L. The dilution factor was included in the equation to adjust for the average percentage of Colorado River water present in the total inflow to the Montebello Forebay. In addition to the direct spreading of Colorado River water, the inflow to the basin consisted of reclaimed water, rising water, and underflow from the adjacent San Gabriel Valley groundwater basin, all of which were derived in part from Colorado River water. Mass balance calculations were performed for each inflow source (Colorado River water, reclaimed water, storm water, rising water, and underflow) based on yearly volume and sulfate concentration to compute the equivalent volume of Colorado River water contributed by each source (see Table VI-1). Each of these values was then added together and the sum was divided by the total inflow to the basin. The resulting dilution factor represented the equivalent average percentage of Colorado River water flowing into the basin.

It should be noted that dilution factors were only derived for the 20 year period beginning in 1954 and ending in 1974. After that point, State Project water became a major source of imported water used for replenishment. Because of the relative volume of State Project water spread (22 percent on an average basis) and because of its low sulfate concentration (35 mg/L), the groundwater system was affected significantly and the groundwater sulfate concentrations began to decrease accordingly. Consequently, it was concluded that the sulfate model was no longer applicable after 1974 and that the calculation of dilution factors (and in fact Colorado River water replacement values) was only valid using pre-1975 sulfate data. Yearly dilution factors thus determined ranged from 34 to 86 percent with an average value of 67.5 percent (see Table VI-1).

To determine if there was a difference in the results obtained with the sulfate model when using the average dilution factor as compared to using the annual dilution factors, replacement values were calculated for several wells using both average and annual factors. These calculations indicated that for a given well, the replacement hydrograph developed using the average dilution factor was almost identical to the hydrograph developed using the annual values. To simplify the subsequent calculations, the average dilution factor was utilized to compute replacement values. Other simplifying assumptions applied to the model included such conditions as: 1) equal proportions of water spread in the Rio Hondo and San Gabriel River spreading grounds, 2) constant water levels, 3) constant pumpage and location of pumpage, and 4) constant quality over time of all inflows to the basin.

Colorado River water replacement values (R_c) computed using the sulfate model were then plotted versus time to derive replacement hydrographs similar to the one shown in Figure VI-1. Ideally, this curve was divided into three phases, each representing a general trend in water movement: 1) the initial phase which represented the time necessary for the replenishment water to travel from the point of recharge to the well, 2) a transition phase which represented the time between no effect and 100 percent effect, and 3) a final phase which represented the time period when the effects of the replenishment water had been fully felt. For the Montebello Forebay wells, the ability to distinguish between each phase was dependent on the quantity and quality of sulfate data available. For 65 percent of the wells evaluated, a lack of data required that portions of the hydrographs be approximated based either on the characteristics of the well itself (such as distance from the spreading grounds, aquifer perforated, and depth to groundwater table) and/or on curves for wells in close

TABLE VI-1. ESTIMATION OF COLORADO RIVER WATER DILUTION FACTOR

Year	Colo.Riv.Water Directly Spread AF X 10^3	Reclaimed Water Directly Spread				Other Inflows - Rising Water and Underflow				Total(i) Equivalent AF X 10^3 Colo.Riv.Water	Total(j) Recharge AF X 10^3	Dilution Factor Equivalent %(k) Colo.Riv.Water
		Amount AF X 10^3 (a)	Sulfate Conc. mg/L(b)	Equivalent % Colo. Riv. Water(c)	Equivalent AF x 10^3(d) Colo.Riv.Water	Amount AF X 10^3 (e)	Sulfate Conc. mg/L (f)	Equivalent % Colo. River Water (g)	Equivalent AF X 10^3(h) Colo.Riv.Water			
1954	12	0	-	0	0	47	124	76	35.7	47.7	84	57
1955	15	0	-	0	0	48	124	76	36.5	51.5	79	65
1956	31	0	-	0	0	43	124	76	32.7	63.7	94	68
1957	38	0	-	0	0	43	124	76	32.7	70.7	105	67
1958	92	0	-	0	0	47	124	76	35.7	127.7	237	54
1959	48	0	-	0	0	46	124	76	35.0	83.0	120	69
1960	70	0	-	0	0	40	124	76	30.4	100.4	133	75
1961	121	0	-	0	0	32	124	76	24.3	145.3	169	86
1962	180	1	107	72	0.7	34	124	76	25.8	206.5	272	76
1963	68	12	109	72	8.7	28	124	76	21.2	97.9	129	76
1964	86	13	156	81	10.5	24	124	76	18.2	114.7	145	79
1965	136	15	128	77	11.5	21	124	76	15.9	163.4	200	82
1966	102	15	123	76	11.3	23	124	76	17.4	130.7	201	65
1967	67	16	123	76	12.1	31	124	76	23.5	102.6	183	56
1968	79	24	119	75	18.0	38	124	76	28.8	125.8	169	74
1969	17	20	104	71	14.2	50	124	76	37.9	69.1	201	34
1970	61	26	97	69	18.0	47	124	76	35.6	114.6	166	69
1971	63	27	110	73	19.6	37	124	76	28.0	110.6	161	69
1972	30	26	109	72	18.8	30	124	76	22.7	71.5	115	62
1973	80	30	106	72	21.5	34	124	76	25.8	127.3	196	65
1974	80	27	105	71	19.3	34	124	76	25.8	125.1	181	69

FOOTNOTES FOR TABLE VI-1

a. Includes flows from Whittier Narrows, Pomona, and San Jose Creek WRPs.

b. Yearly averages of Whittier Narrows, Pomona, and San Jose Creek WRP effluent sulfate concentrations, obtained from LACSD monitoring records.

c. Assume native groundwater sulfate concentration equal to 30 mg/l.
$$\text{Equivalent \% Colorado River Water} = \frac{\text{Reclaimed water sulfate concentration} - 30}{\text{Reclaimed water sulfate concentration}} \times 100\%$$

d. Equivalent AFX10^3 Colorado River Water = Amount (AFX10^3) X Equivalent % Colorado River Water.

e. Includes both subsurface inflow and rising water.

f. Based on available data, sulfate concentration of rising water and underflow assumed to be equivalent to sulfate concentration of Well 2S/11W-5N4 located in the vicinity of occurrence of both rising water and underflow, average sulfate concentration for this well equal to 124 mg/l.

g. Assume native groundwater sulfate concentration equal to 30 mg/l.
$$\text{Equivalent \% Colorado River Water} = \frac{\text{Rising water and underflow sulfate concentration} - 30}{\text{Rising water and underflow sulfate concentration}} \times 100$$

h. Equivalent AFX10^3 Colorado River Water = Amount (AFX10^3) X Equivalent % Colorado River Water.

i. Total Equivalent Colorado River Water AFX10^3 =
Equivalent AFX10^3 Colorado River Water (directly spread water + reclaimed water + rising water/underflow).

j. Includes water directly spread (Colorado River, reclaimed, storm) plus subsurface inflow, and rising water.

k. $$\text{Dilution Factor} = \frac{\text{Total Equivalent Colorado River Water}}{\text{Total Recharge}} \times 100$$

The Average Dilution Factor = 67.5%.

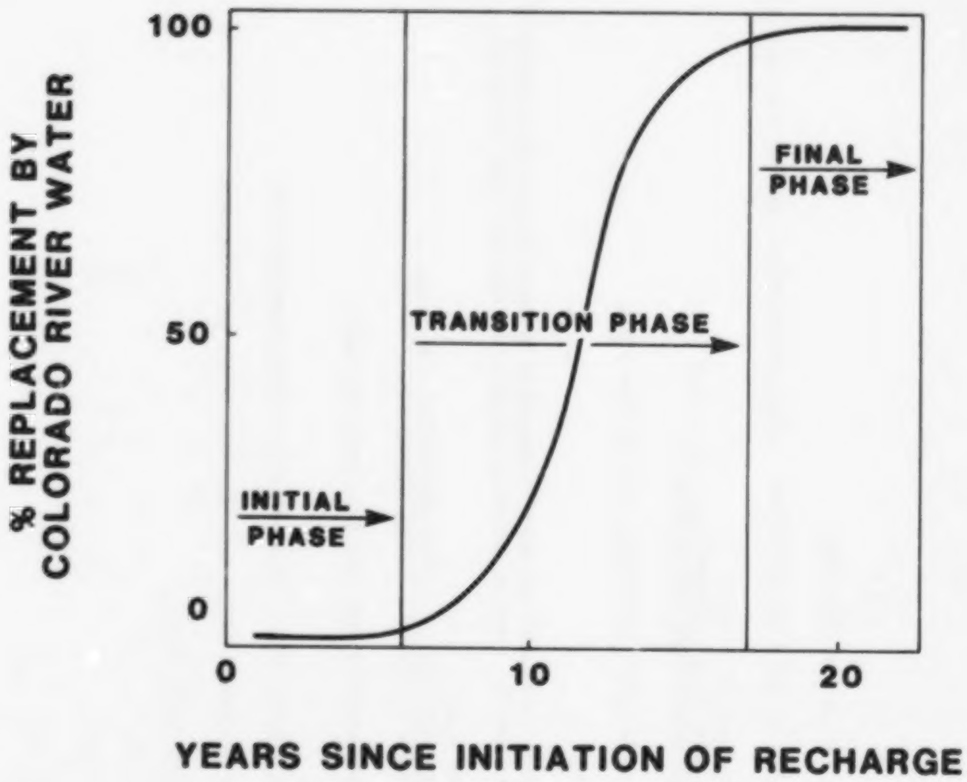


FIGURE VI-1 REPLACEMENT HYDROGRAPH

proximity with similar hydrogeologic characteristics. Those with the most complete data were part of the key well monitoring network established for the basin-wide water quality monitoring program (VI-3).

Yearly R_c values were then taken from the curves and converted to reclaimed water replacement values in a two step process which was based on the assumption that reclaimed water had moved through the groundwater basin at the same rate as Colorado River water. Given the eight year lag between the initiation of recharge using Colorado River water (1954) and reclaimed water (1962) and the relative proportions of reclaimed water spread each year (see Table VI-2), percent replacement values for reclaimed water (R_r) were computed as follows:

Step 1

- Annual R_c values for years 1954-1969 were shifted to account for the eight year lag between spreading reclaimed water and Colorado River water such that:

$$R_c(1954) \rightarrow R'_c(1962)$$

$$R_c(1955) \rightarrow R'_c(1963)$$

$$R_c(1956) \rightarrow R'_c(1964)$$

$$\vdots \qquad\qquad \vdots$$

$$R_c(1969) \rightarrow R'_c(1977)$$

Step 2

- The R'_c values were multiplied by the proportional factors (F) listed in Table VI-2 which reflected the proportion of reclaimed water making up the total inflow to the Forebay. Selection of the correct F factor was based on the year the replacement values first indicated that the recharge water had reached the well, i.e., if the water spread in 1962 first reached the well in 1963, the annual reclaimed water replacement values would be:

$$R_r(1962) = 0$$

$$R_r(1963) = R'_c(1963) \times F(1962)$$

$$R_r(1964) = R'_c(1964) \times F(1963)$$

$$R_r(1965) = R'_c(1965) \times F(1964)$$

$$\vdots \qquad\qquad \vdots$$

$$R_r(1977) = R'_c(1977) \times F(1976)$$

or if the water first spread in 1962 reached the well in 1966:

TABLE VI-2
PERCENTAGE OF RECLAIMED WATER MAKING UP TOTAL INFLOW TO THE MONTEBELLO FOREBAY

Year	LOCAL WATER					IMPORTED WATER			RECLAIMED WATER				Total Inflow AFX10	Percent Reclaimed of Total Inflow F (a)
	Subsurface Inflow AFX10^3	Rising Water AFX10^3	Storm Inflow AFX10^3	Local Precipitation AFX10^3	Local Water Subtotal AFX10^3	Colorado River water AFX10^3	State Project water AFX10^3	Imported Water Subtotal AFX10^3	Whittier Narrows WRP AFX10^3	San Jose Creek WRP AFX10^3	Pomona WRP AFX10^3	Reclaimed Water Subtotal AFX10^3		
1962	23	11	34	23	91	180	0	180	1	0	0	1	272	0.4
1963	21	7	9	12	49	68	0	68	12	0	0	12	129	9.3
1964	21	3	11	11	46	86	0	86	13	0	0	13	145	9.0
1965	19	2	15	13	49	136	0	136	15	0	0	15	200	7.5
1966	17	6	41	20	84	102	0	102	15	0	0	15	201	7.5
1967	17	14	47	22	100	67	0	67	16	0	0	16	183	8.7
1968	21	17	16	12	66	79	0	79	18	0	6	24	169	14.2
1969	24	26	88	26	164	17	0	17	14	0	6	20	201	10.0
1970	24	23	21	11	79	61	0	61	17	0	9	26	166	15.7
1971	23	14	22	12	71	63	0	63	19	0	8	27	161	16.8
1972	24	6	18	11	59	30	0	30	18	0	8	26	115	22.6
1973	26	8	30	22	86	80	0	80	14	8	8	30	196	15.3
1974	27	7	26	14	74	80	0	80	13	8	6	27	181	14.9
1975	26	4	18	13	61	11	56	67	15	7	5	27	155	17.4
1976	28	1	18	5	52	1	34	35	12	9	5	26	113	23.0
1977	32	0	19	11	62	12	14	26	10	13	1	24	112	21.4

(a) Proportional Factors used to develop reclaimed water replacement values.

$R_r(1962) = 0$

$R_r(1963) = 0$

$R_r(1964) = 0$

$R_r(1965) = 0$

$R_r(1966) = R'_c(1966) \times F(1962)$

$R_r(1967) = R'_c(1967) \times F(1963)$

$R_r(1968) = R'_c(1968) \times F(1964)$

$$\begin{array}{cc} \vdots & \vdots \end{array}$$

$R_r(1977) = R'_c(1977) \times F(1973)$

Reclaimed Water Replacement Estimates for Key Wells

One other important aspect of this work was to provide a basis for evaluating the impacts of replenishment by determining the relative proportions of reclaimed water in the ten Montebello Forebay wells selected for the water quality and toxicological characterizations (see Chapters III and IV). In this manner, the identification of contaminants in a given well could be correlated with the proportion of reclaimed water in the well at the time a sample was collected. The traditional method for assessing impacts has been to evaluate the wells, isolate contaminants, and based on the water quality characteristics of the replenishment waters, determine which source is the primary contributor. One of the problems encountered when using this method, is that the current quality of the replenishment sources which is being evaluated could easily be different than the quality of the waters previously spread (i.e., waters which have impacted the wells). Correlations between proportions of reclaimed water in wells and the presence of contaminants provide a means for addressing this issue. Reclaimed water replacement values for the ten wells derived using the procedures described above, have been presented in Table VI-3.

Proportion of Reclaimed Water Pumped

Once the reclaimed water replacement values had been derived for all of the Montebello Forebay wells, the next step in the development of exposure data involved grouping wells and associated R_r values according to water district. The proportion of reclaimed water in the pumped groundwater for a given water system was then determined using available annual well production data. This was done for 32 water systems within the study area (see Figure VI-2). It was necessary to determine the proportion of reclaimed water in the pumped groundwater to account for yearly fluctuations in well production which directly influenced the volume of reclaimed water being pumped from wells. For example, certain wells which had received significant percentages of reclaimed water were either out of service during a portion of the study period or produced little water. A similar decrease in production was observed for many wells not receiving reclaimed water. Both situations significantly affected the amount of

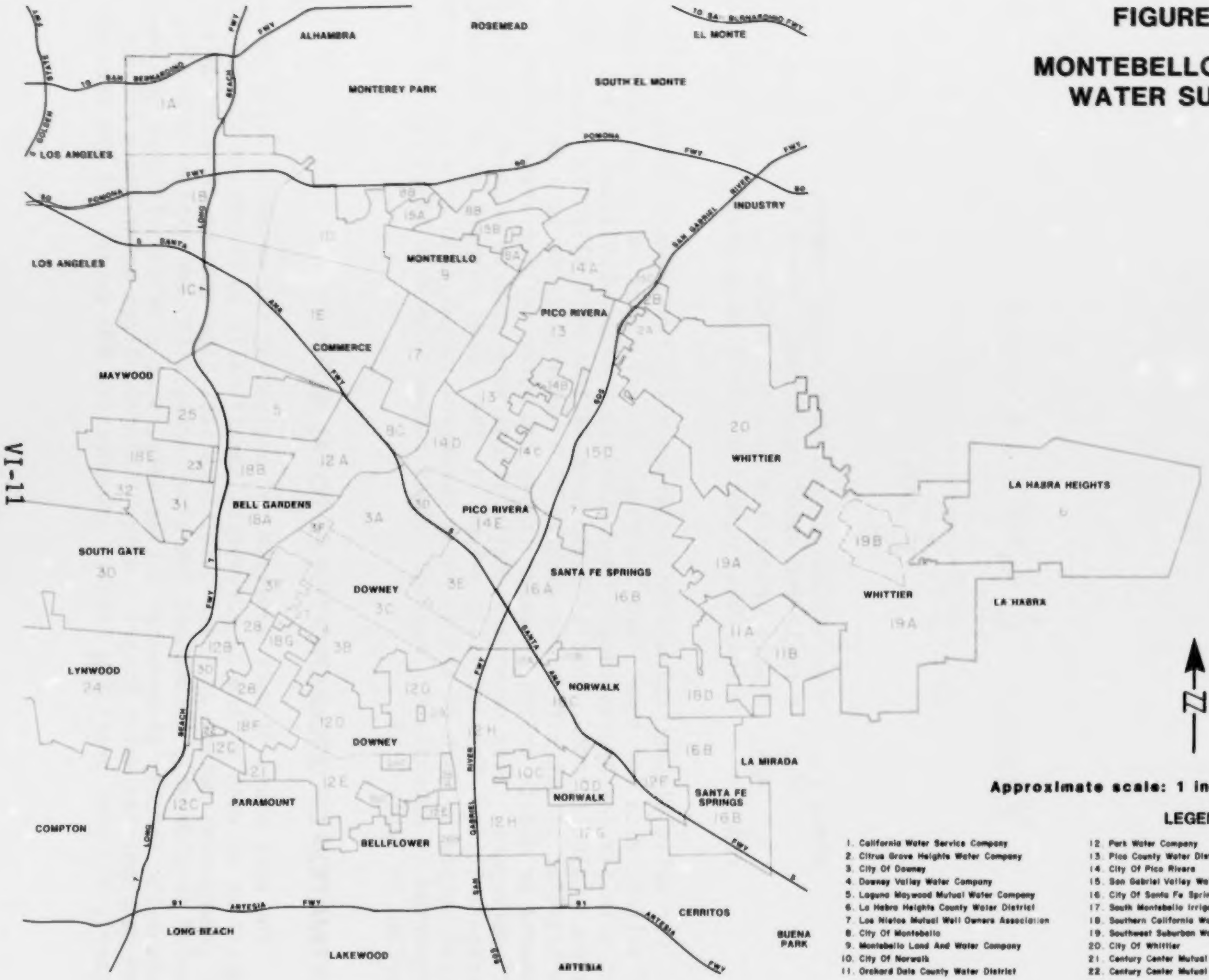
TABLE VI-3 ESTIMATES OF RECLAIMED WATER PROPORTIONS IN MONTEBELLO FOREBAY WELLS[a]

Year	Percentage of Reclaimed Water									
	Well 2947Q	Well 1514A	Well 2958A	Well 1566A	Well 1580J	Well 1621MM	Well 2907	Well 1591H	Well 1620GG	Well 1562E
1962	0	0	0	0	0	0	0	0	0	0
1963	0	0	0	0	0	0	0	0	0	0
1964	0	0	0	0	1	2	0	0	0	0
1965	0	0	0	0	2	5	0	0	4	0
1966	0	0	0	0	3	4	4	0	6	1
1967	0	0	0	0	4	4	4	3	5	1
1968	0	0	0	0	6	5	3	5	6	1
1969	0	0	<1	0	13	8	3	5	7	1
1970	0	0	<1	0	11	6	4	7	13	2
1971	0	0	1	0	16	12	8	7	9	4
1972	0	0	1	7	17	14	6	11	15	3
1973	0	0	2	9	23	21	11	8	17	16
1974	0	0	2	4	15	15	13	12	23	17
1975	0	1	3	3	15	12	18	13	15	23
1976	0	2	4	8	14	14	13	17	14	15
1977	0	3	6	7	17	18	12	12	17	15
1978	0	4	5	6	13	17	16	12	21	13
1979	0	4	4	10	6	7	21	14	19	14
1980	0	4	5	14	10	11	18	18	8	13
1981	0	3	7	19	12	13	8	17	11	8

(a) See Chapter III for location map and hydrogeologic information on wells.

FIGURE VI-2

MONTEBELLO FOREBAY WATER SUPPLIERS



Approximate scale: 1 inch equals 1.35 miles

LEGEND

1. California Water Service Company
2. Citrus Grove Heights Water Company
3. City Of Downey
4. Downey Valley Water Company
5. Laguna Maywood Mutual Water Company
6. La Habra Heights County Water District
7. Los Nietos Mutual Well Owners Association
8. City Of Montebello
9. Montebello Land And Water Company
10. City Of Norwalk
11. Orchard Dale County Water District
12. Park Water Company
13. Pico County Water District
14. City Of Pico Rivera
15. San Gabriel Valley Water Company
16. City Of Santa Fe Springs
17. South Montebello Irrigation District
18. Southern California Water Company
19. Southwest Suburban Water Company
20. City Of Whittier
21. Century Center Mutual Water Association
22. Century Center Mutual Water Company
23. Chansell Mutual Water Company
24. City Of Lynwood
25. Maywood Mutual Water Company
26. Peerless Land And Water Company
27. Pomering Tract Water Association
28. Rancho Los Amigos
29. Rancho Santa Gertrudes Mutual Water Company
30. City Of South Gate
31. Tract N° 180 Mutual Water Company
32. Tract N° 349 Mutual Water Company

reclaimed water making up a purveyor's water supply. Mass balance calculations were performed for each of the 32 purveyors using the appropriate R_r values and annual well production data as follows:

$$P_r(1962) = \frac{\sum_{i=1}^{n} R_{r_i}(1962) \times AFY_i\ (1962)}{\sum_{i=1}^{n} AFY_i(1962)}$$

$$\vdots \qquad\qquad \vdots$$

$$P_r(1977) = \frac{\sum_{i=1}^{n} R_{r_i}(1977) \times AFY_i(1977)}{\sum_{i=1}^{n} AFY_i(1977)}$$

where P_r = percentage of reclaimed water pumped,
R_{r_i} = reclaimed water replacement values for well i,
AFY_i = well production in AFY for well i,
and n = the total number of wells for a given water company.

For wells without calculated reclaimed water replacement values due to lack of sulfate data for input into the model, R_r values for wells in close proximity and with similar hydrogeologic characteristics were substituted in the mass balance calculations. Some of these calculations were slightly complicated due to transfer of water from one subarea of a water district to a second or third subarea or due to shifts in water rights and water service areas between individual purveyors. When necessary, calculations were made to account for these irregularities. The resulting values for the annual proportion of reclaimed water pumped by each of the 32 water purveyors ranged from zero to 23 percent as presented in Appendix N. Average values ranged from zero to 11 percent as summarized in Table VI-4.

ESTIMATION OF GROUNDWATER IN TOTAL SUPPLY

The next phase of work consisted of evaluating the water delivery characteristics of each of the 32 purveyors, specifically to determine the percentage of groundwater making up their total supplies. The make-up of water delivered varied considerably throughout the study area, with some systems providing Montebello Forebay groundwater exclusively, some providing Forebay groundwater and Metropolitan Water District water (Colorado River water/State Project water), and some providing Forebay groundwater, MWD water, and San Gabriel

TABLE VI-4

RECLAIMED WATER ESTIMATES FOR THE MONTEBELLO FOREBAY

Water Purveyor	Map Reference Number (a)	Average % Reclaimed Water Pumped From Wells (b)	Average % Groundwater Making Up Total Supply (c)	Average % Reclaimed Water Making Up Total Supply (d)
California Water Service Co.	1A	I(e)	0	0
	B	<0.1	46	<0.1
	C	<1.3	100	<1.3
	D	0	27	0
	E	1.5	74	<1.1
Citrus Grove Heights Water Co.	2A	2.8	60	2.6
	B	7.2	89	7.1
City of Downey	3A	7.7	100	7.7
	B	5.4	28	<1.6
	C	6.6	74	5.2
	D	9.0	100	9.0
	E	5.5	100	5.5
	F	5.9	100	5.9
Downey Valley Water Co.	4	5.7	100	5.7
Laguna Maywood Mutual Water Co.	5	ND(f)	ND	ND
La Habra Heights County Water Dist.	6	9.2	100	9.2
Los Nietos Mutual Well Owners Assoc.	7	9.8	100	9.8
City of Montebello	8A	7.6	100	7.6
	B	0(g)	0	0
	C	ND	ND	ND
Montebello Land & Water Co.	9	5.8	100	5.8
City of Norwalk	10A	5.7	95	5.7
	B	9.2	76	6.2
	C	1.5	100	1.5
	D	0	100	0

TABLE VI-4 (Cont.)

RECLAIMED WATER ESTIMATES FOR THE MONTEBELLO FOREBAY

Water Purveyor	Map Reference Number (a)	Average % Reclaimed Water Pumped From Wells (b)	Average % Groundwater Making Up Total Supply (c)	Average % Reclaimed Water Making Up Total Supply (d)
Orchard Dale County Water Dist.	11A	9.2	84	7.7
	B	I	0	0
Park Water Co.	12A	6.1	51	<3.2
	B	1.3	100	1.3
	C	<1.5	66	<0.1
	D	<1.5	100	<1.5
	E	<1.5	72	<1.3
	F	<0.8	10	<0.1
	G	<0.8	69	<0.6
	H	<0.8	97	<0.8
Pico County Water Dist.	13	7.8	100	7.8
City of Pico Rivera	14A	8.9	60	<2.0
	B	7.9	74	4.1
	C	7.9	100	7.9
	D	ND	ND	ND
	E	6.2	100	6.2
San Gabriel Valley Water Co.	15A	I	0	0
	B	3.3	32	0.9
	C	4.7	53	2.9
	D	10.8	100	10.8
City of Santa Fe Springs	16A	9.0	78	6.2
	B	ND	ND	ND
South Montebello Irrigation Dist.	17	10.4	100	10.4

TABLE VI-4 (Cont.)

RECLAIMED WATER ESTIMATES FOR THE MONTEBELLO FOREBAY

Water Purveyor	Map Reference Number (a)	Average % Reclaimed Water Pumped From Wells (b)	Average % Groundwater Making Up Total Supply (c)	Average % Reclaimed Water Making Up Total Supply (d)
Southern California Water Co.	18A	3.9	44	<1.5
	B	<4.6	92	<3.9
	C	3.5	57	1.9
	D	0	2	0
	E	<0.6	100	<0.6
	F	1.0	100	1.0
	G	1.0	64	<0.9
Southwest Suburban Water Co.	19A	I	0	0
	B	<2.8	22	<0.6
City of Whittier	20	0.2	1	<0.1
Century Center Mutual Water Assoc.	21	1.2	100	1.2
Century City Mutual Water Co.	22	0	100	0
Chansall Mutual Water Co.	23	2.5	100	2.5
City of Lynwood	24	<0.2	76	<0.2
Maywood Mutual Water Co.	25	0	87	0
Peerless Land & Water Co.	26A	0.5	100	0.5
	B	0.5	100	0.5
	C	1.1	100	1.1
	D	<0.1	67	<0.1

TABLE VI-4 (Cont.)

RECLAIMED WATER ESTIMATES FOR THE MONTEBELLO FOREBAY

Water Purveyor	Map Reference Number (a)	Average % Reclaimed Water Pumped From Wells (b)	Average % Groundwater Making Up Total Supply (c)	Average % Reclaimed Water Making Up Total Supply (d)
Pomering Tract Water Assoc.	27	4.6	64	<1.3
Rancho Los Amigos	28	2.3	100	2.3
Rancho Santa Gertrudes Mutual Water Co.	29	<1.5	100	<1.5
City of South Gate	30	11.1	72	<0.5
Tract No. 180 Water Co.	31	0	100	0
Tract No. 349 Mutual Water Co.	32	0	100	0

FOOTNOTES

(a) For study area map see Figure VI-2.
(b) Percentage of reclaimed water pumped from Montebello Forebay wells averaged over 1961-77.
(c) Proportion of Montebello Forebay groundwater in total supply averaged over 1961-77.
(d) Proportion of reclaimed water in total supply averaged over 1961-77.
(e) I = entire supply derived from imported water, no Montebello Forebay groundwater pumped.
(f) ND = not determined, entire area is industrial.
(g) Area development did not begin until 1971-72.

Valley groundwater. To clarify the situation, Bookman-Edmonston Engineering, Inc., investigated each purveyor to delineate such operational characteristics as the service area boundaries of the water systems, the number of residential and commercial connections, the different sources of water supplied, the annual groundwater production levels, the location of producing facilities, and chlorination practices. Changes in delivery practice and service area were also documented in addition to quantifying deliveries made between different water districts. Information was obtained from the individual districts, the Public Utilities Commission, the County Health Department, private hydrogeologic and engineering consultants, and reports on file with Bookman-Edmonston Engineering, Inc. Some of the general service characteristics of each purveyor have been presented in Table VI-5.

Final results of the investigation provided estimates of the annual percentages of Montebello Forebay groundwater making up the total supply of a water system as summarized in Table VI-4 (for specific details see Appendix N). In some cases, groundwater estimates were determined for subareas of water districts, selected on the basis of geography, pressure zones which separated water service, or location of Metropolitan Water District's feeders. The 32 purveyors were divided into 73 subsections, 31 of which received Montebello Forebay groundwater entirely, five of which received MWD water entirely, 33 of which received a blend of waters, and four of which were excluded from further analysis because they were not residential areas.

ESTIMATION OF RECLAIMED WATER IN TOTAL SUPPLY

The final step in deriving the percentages of reclaimed water making up the study area's water supply consisted of coordinating the annual proportions of reclaimed water derived for the 32 water purveyor's groundwater supplies with the estimates of how much Montebello Forebay groundwater each purveyor delivered. The percentage of reclaimed water making up the total supply was calculated as follows:

$$T_r = G \times P_r \times 100$$

where T_r = percentage of reclaimed water making up the total supply,
G = percentage of Montebello Forebay groundwater making up the total supply,
and P_r = percentage of reclaimed water pumped with groundwater.

The proportion of reclaimed water in the total supplies for the 32 purveyors ranged from zero to 23 percent; seventeen year averages were somewhat lower ranging from zero to 11 percent. A summary of these values is presented in Table VI-4, with more specific information included in Appendix N.

It should be emphasized at this point that the values presented in Table VI-4 only represent gross estimates of actual population exposure. This is primarily due to the approximate nature of the sulfate model, the uncertainties associated with the quality of the sulfate data (or lack of data), and difficulties encountered in the evaluation of groundwater deliveries within the study area. Fortunately, the simplicity of the sulfate model inherently pro-

TABLE VI-5

SERVICE CHARACTERISTICS OF 32 MONTEBELLO FOREBAY AND CENTRAL BASIN WATER PURVEYORS

Name of Purveyor		Number of Residential Connections	Estimated(a) Population	Water Sources(b)
California Water Service Co.		24,550	82,000	MWD, MFGW
Citrus Grove Heights Water Co.(c)		220	750	MFGW, SGVGW
City of Downey		16,000	54,000	MWD, MFGW
Downey Valley Water Co.		30	100	MFGW
Laguna Maywood Mutual Water Co.		0	(d)	MWD, MFGW
La Habra Heights County Water Dist.		1,600	5,440	MFGW
Los Nietos Mutual Well Owners Assoc.		86	290	MFGW
City of Montebello		1,122	3,815	MWD, MFGW
Montebello Land & Water Co.		3,800	12,920	MFGW
City of Norwalk		1,076(e)	3,660	MWD, MFGW, SGVGW
Orchard Dale County Water District		3,742	15,000	MWD, MFGW
Park Water Co.		23,498	79,893	MWD, MFGW
Pico County Water Dist.		5,100	17,340	MFGW
City of Pico Rivera		7,134	24,255	MFGW, SGVGW
San Gabriel Valley Water Co.		8,350	28,390	MWD, MFGW, SGVGW
City of Santa Fe Springs		3,840	13,060	MFGW, SGVGW
South Montebello Irrigation Dist.		1,600	5,540	MFGW
Southern California Water Co.		18,319	62,285	MWD, MFGW
Southwest Suburban Water Co.		900		16,436 MFGW, SGVGW
City of Whittier		10,026	34,090	MFGW, SGVGW
Century Center Mutual Water Assoc.		132(f)	450	MFGW
Century City Mutual Water Co.		105	357	MFGW
Chansall Mutual Water Co.		ND(g)	ND	MFGW
City of Lynwood		9,200	31,280	MWD, MFGW
Maywood Mutual Water Co.		1,901	6,463	MWD, MFGW
Peerless Land and Water Co.		1,085	3,689	MWD, MFGW
Pomering Tract Water Assoc.		54	184	MWD, MFGW
Rancho Los Amigos		ND	ND	MFGW
Rancho Santa Gertrudes Mutual Water Co.		11	37	MFGW
City of South Gate		13,600	46,240	MWD, MFGW
Tract No. 180 Water Co.		650	2,210	MFGW
Tract No. 349 Mutual Water Co.		ND	ND	MFGW
	TOTAL	157,731	550,174	

TABLE VI-5 (Cont.)

Footnotes

(a) With the exception of California Water Service Co., Los Nietos Mutual Well Owners Assoc., Orchard Dale County Water Dist., Southwest Suburban Water Co., and Century Center Mutual Water Assoc., population estimates based on 3.4 people per connection.

(b) Water sources include: MWD = Metropolitan Water District imported water; MFGW = Montebello Forebay groundwater, and SGVGW = San Gabriel Valley groundwater.

(c) Service area received Montebello Forebay groundwater exclusively until 1970 when the water service for one section of the district was transferred to the City of Whittier (San Gabriel Valley groundwater); the remaining area continued receiving Montebello Forebay groundwater until 1975 when water service was transferred to the City of Whittier.

(d) Only industrial users.

(e) Portion of residential connections determined by population based on 0.29 connections/population.

(f) Based on 0.29 connections/population.

(g) ND = Not determined.

vided conservative estimates of reclaimed water production through utilization of a lower than average native groundwater sulfate concentration and a higher than average sulfate concentration for Colorado River water. The model's results were also influenced by the application of a highly conservative dilution factor to the replacement value derivations. In addition, knowledge of the historical proportions of the different replenishment sources allowed for an upper limit to be set for all reclaimed water estimates; that is, for any given year, the maximum proportion of reclaimed water entering the Forebay was 23 percent which logically implied that the maximum amount of reclaimed water that could reach and be drawn from a well was 23 percent. Consequently, the theoretical range of reclaimed water exposure values was zero to 23 percent. The estimation of values lying between the two limits was subject to the most error and highly dependent not only on the quality of sulfate data, but also on the estimates of how much Montebello Forebay groundwater a particular purveyor delivered. These uncertainties were somewhat alleviated in the latter case by the high proportion of the purveyors or subareas of purveyors serving Montebello Forebay groundwater exclusively. Nevertheless, the overall error attributed to the intermediate population exposure estimates ranged from 10 to 20 percent.

DETERMINATION OF EXPOSURE LEVEL

The fact that the reclaimed water percentages thus derived were approximations was also taken into account when deriving the population based exposure information for the epidemiology study. Rather than using numerical values of exposure, the decision was made to compare population groups on the basis of less specific designations such as high and low exposure. Given the varying exposure patterns, the question then became, how does one define high and low exposure to reclaimed water? Is it more significant to ingest higher proportions of reclaimed water over a short period of time, or to ingest moderate to low proportions over a long period of time? Because there was no satisfactory answer to these questions, the following definitions of high and low exposure were arbitrarily selected for the epidemiological analyses of the earliest set of vital statistics data discussed in Chapter VII:

High Exposure - Water systems and subareas of water systems that have supplied water containing $\geq$ 5 percent reclaimed water for one or more years prior to 1970-71.

Low Exposure - Water systems and subareas of water systems that have supplied water containing < 5 percent reclaimed water for one or more years prior to 1970-71.

Those water systems and sections of water systems which had served Metropolitan Water District water exclusively or Montebello Forebay groundwater which had not been impacted by reclaimed water, were classified as central control districts.

The numerical exposure estimates for the 32 water purveyors were subsequently categorized as receiving high or low proportions of reclaimed water or as controls. A breakdown of water districts according to exposure level is summarized in Table VI-6. Figure VI-3 shows the general location of the two exposure areas and the central control areas. A graphical representation of the changes in the proportions of reclaimed water supplied over time for each level of exposure is presented in Figure VI-4. This information was subsequently incorporated into the epidemiology study as described in the next chapter.

TABLE VI-6

IDENTIFICATION OF WATER DISTRICTS ACCORDING TO LEVEL OF EXPOSURE FOR 1969-71 EPIDEMIOLOGICAL ANALYSIS[a],[b]

HIGH RECLAIMED WATER AREA	LOW RECLAIMED WATER AREA	CENTRAL CONTROL AREA
2A,B-Citrus Grove Heights Water Co.	1C,E-California Water Co.	1A,B,D-California Service Co.
3A,D,E,F - City of Downey	3B, C - City of Downey	10D - City of Norwalk
4-Downey Valley Water Co.	9-Montebello Land & Water Co.	11B-Orchard Dale County Water District
6-La Habra Heights County Water District	10C-City of Norwalk	12B,F,G-Park Water Co.
7-Los Nietos Mutual Well Owners Assoc.	12A,C,D,E,H-Park Water Co.	15A-San Gabriel Valley Water Co.
8A-City of Montebello	15B-San Gabriel Valley Water Co.	18D-Southern California Water Co.
10A,B-City of Norwalk	18A,B,C,E,F,G-Southern California Water Co.	19A-Southwest Sub-Urban Water Co.
11A-Orchard Dale County Water District	19B-Southwest Suburban Water Co.	22-Century City Mutual Water Co.
13-Pico County Water Dist.	20-City of Whittier	24-City of Lynwood
14A,B,C,E-City of Pico Rivera	21-Century Center Mutual Water Assoc.	25-Maywood Mutual Water Co.
15C,D-San Gabriel Valley Water Co.	23-Chansall Mutual Water Co.	26A,B,D-Peerless Land & Water Co.
16A-City of Santa Fe Springs	26C-Peerless Land & Water Co.	30-City of Southgate
17-South Montebello Irrigation District	27-Pomering Tract Water Assoc.	31-Tract No. 180 Water Co.
	28-Rancho Los Amigos	32-Tract No. 349 Mutual Water Co.
	29-Rancho Santa Gertrudes Mutual Water Co. District	

Footnotes

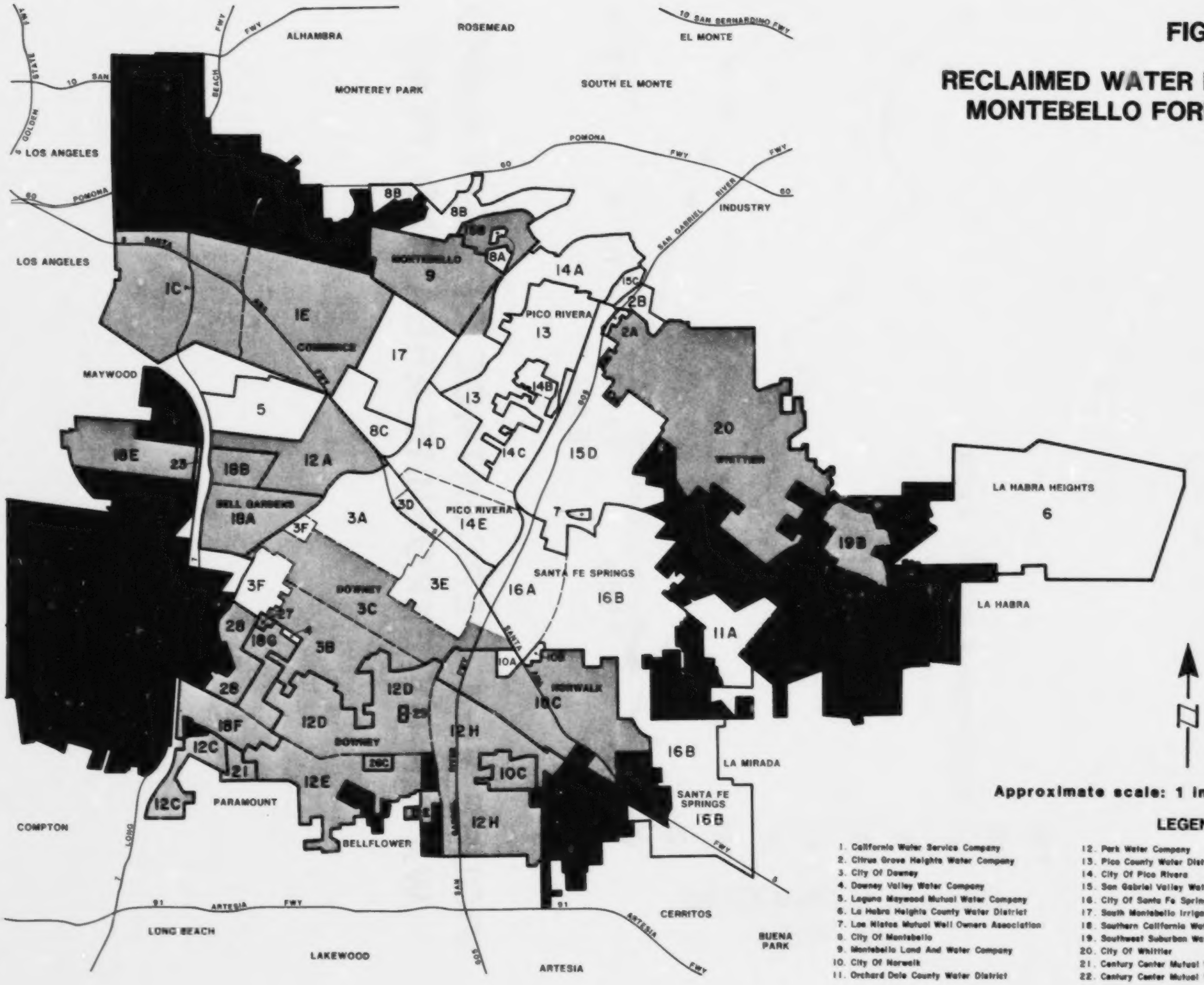
(a) For discussion of 1969-71 epidemiology analyses, see Chapter VII.

(b) Numbers in table denote map reference numbers for Figure VI-2.

(c) Water districts 5, 8C, 14D, and 16B were not included because all users were industrial/commercial, water district 8B was not included because water service only began in 1971-72.

FIGURE VI-3

RECLAIMED WATER EXPOSURE PATTERNS FOR MONTEBELLO FOREBAY WATER SUPPLIERS



KEY TO WATER SUPPLIERS

□ HIGH EXPOSURE

▨ LOW EXPOSURE

■ CONTROL

Approximate scale: 1 inch equals 1.35 miles

LEGEND

1. California Water Service Company
2. Citrus Grove Heights Water Company
3. City Of Downey
4. Downey Valley Water Company
5. Laguna Maywood Mutual Water Company
6. La Habra Heights County Water District
7. Los Nietos Mutual Well Owners Association
8. City Of Montebello
9. Montebello Land And Water Company
10. City Of Norwalk
11. Orchard Dale County Water District
12. Park Water Company
13. Pico County Water District
14. City Of Pico Rivera
15. San Gabriel Valley Water Company
16. City Of Santa Fe Springs
17. South Montebello Irrigation District
18. Southern California Water Company
19. Southwest Suburban Water Company
20. City Of Whittier
21. Century Center Mutual Water Association
22. Century Center Mutual Water Company
23. Chansell Mutual Water Company
24. City Of Lynwood
25. Maywood Mutual Water Company
26. Peerless Land And Water Company
27. Pomering Tract Water Association
28. Rancho Los Amigos
29. Rancho Santa Gertrudes Mutual Water Company
30. City Of South Gate
31. Tract N° 180 Mutual Water Company
32. Tract N° 349 Mutual Water Company

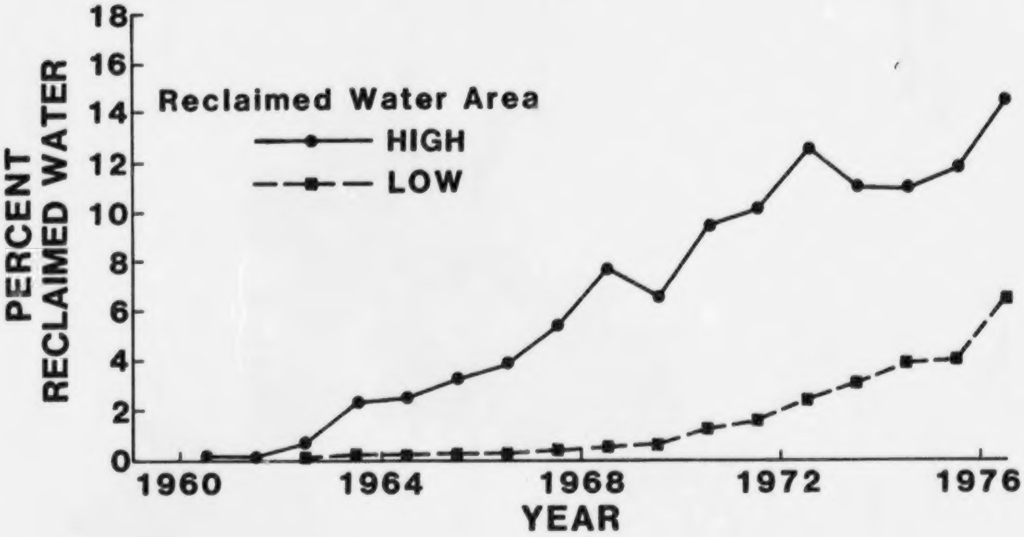


FIGURE VI-4 PERCENTAGE OF RECLAIMED WATER BY EXPOSURE AREA AND YEAR

REFERENCES

VI-1. Hasset JP Jr, Lee GF. Sterols in natural water and sediment. Water Research 11:983, 1977.

VI-2. Bookman and Edmonston Consulting Civil Engineers, Inc., Management of Ground Water Quality in the Central and West Basin Water Replenishment District, Central and West Basin Water Replenishment District, Downey California, 1970.

VI-3. Bookman-Edmonston Engineering, Inc., Annual Report on Results of Water Quality Monitoring, Water Year 1979-80. Central and West Basin Water Replenishment District, Downey, California, 1981.

CHAPTER VII
EPIDEMIOLOGY

INTRODUCTION

While numerous epidemiologic investigations have demonstrated an association between drinking water and increased disease or death rates, few studies have focused on the potential health effects arising from the practice of reusing treated wastewater. During a drought period in 1940 in Ottumwa, Iowa (VII-1), and again in 1956-57 in Chanute, Kansas (VII-2), reclaimed water was fed directly into the municipal drinking water supply. Although concern about health effects related to the possible presence of microorganisms was aroused, no such effects were observed. It should be noted, however, that the manner in which cases were sought was not comprehensive in that no systematic morbidity studies were undertaken. A different outcome was observed in 1959, when the Ruhr River was used as a source of potable water in Essen, Germany (VII-3). Here, it was determined that the water supply was responsible for causing a non-bacterial gastroenteritis among seven percent of the city's population.

In more recent times, reclaimed water has been used on a regular basis in various localities to supplement fresh water sources either for drinking or non-potable uses. Concern has been expressed by a World Health Organization consultant group that inferences about the use of reclaimed water are typically drawn from observed water quality characterization studies with little or no follow-up of health effects in people (VII-4). One study that did follow-up consumers found no evidence of excessive occurrence of infectious diseases even though extensive case-finding procedures were employed (VII-5). Another study which investigated the causes of death among people exposed to reclaimed water found no statistically significant association between water reuse and mortality (VII-6).

In a recent publication sponsored by the National Academy of Sciences - National Research Council (VII-7), epidemiologic studies of water-associated hazards were reviewed to determine if results from population-based investigations supported earlier findings from animal studies or other forms of laboratory investigations. The subcommittee preparing the report felt that there were several problems inherent in epidemiologic methodology which made it difficult to detect low dose effects with any degree of assurance. First, it was noted that causal relationships that might actually exist were weakened by imprecise data pertaining to the existence, concentration, or consumption level of potential etiologic agents. Second, observed positive or negative associations were usually quite small and, based on statistical tests, might have been due entirely to chance. Third, smoking behavior, dietary habits, use of alcohol or drugs, occupation, and other factors could confound, and thereby possibly negate, any statistical associations between drinking water and a specific disease. Fourth, epidemiologic studies have not always taken into account the time that must elapse between initial exposure and the appearance of disease for conditions such as cancer. Due to the length of induction periods, a specific cancer today might be related to exposure to a carcinogenic substance no longer present, that existed five to 20 years earlier.

It should be noted, however, that like any analytical tool, epidemiology has a sensitivity relative to the experimental setting. Recognition of this fact, and utilization of epidemiology particularly along with other disciplines as instruments for evaluating pollutants in the environment continue to prove extremely useful in assessing the health effects of waterborne contaminants.

GROUNDWATER REPLENISHMENT STUDY

The University of California at Los Angeles (UCLA) School of Public Health was subcontracted to conduct a multi-staged epidemiological investigation regarding the health effects of water reuse by groundwater replenishment. The geographic subject of this study was the Montebello Forebay area of Los Angeles County where groundwater replenishment using treated wastewater had occurred since 1962. Estimates of population exposure (see Chapter VI) for the area at large, demonstrated that domestic water supplies derived from groundwater contained up to 23 percent reclaimed water on an annual basis with long term averages ranging up to 11 percent. On the basis of these estimates, water service areas for the 32 water purveyors supplying the Montebello Forebay were categorized as high exposure areas (receiving five percent or more reclaimed water for at least one water year prior to 1970-71), low exposure areas (receiving less than five percent reclaimed water for at least one water year prior to 1970-71), or control areas (not receiving reclaimed water).

A second control group was included in the study for further comparison. The "northwest control" area was chosen on the basis of its water supplies (the population had received no groundwater recharged with reclaimed water) and the demographic and socioeconomic characteristics of the residents. The geographic location of the exposed and control areas is shown in Figure VII-1.

The epidemiology study focused on a broad spectrum of health concerns that potentially could be attributed to constituents in drinking water. Health parameters evaluated included: mortality patterns utilizing information from death certificates, incident cases of cancer, infant mortality patterns utilizing information from death certificates linked to birth certificates, birth outcome patterns utilizing data derived from birth records such as the occurrence of low birth weights or congenital malformations, and infectious disease patterns.

The epidemiologic monitoring activities were divided into three temporal phases: 1969-71, 1972-78, 1979-80. Census data were available only for the 1969-71 and 1979-80 evaluations. A cancer surveillance program established in 1972 provided incidence data for the 1972-78 and 1979-80 time periods. Also included in the investigation was a household survey of women, conducted in 1981, which compared the general health status of women residing in the high reclaimed water area to that of women residing in the central control area, and a computer simulation analysis which modeled the theoretical relationship between exposure to contaminants in drinking water and measurable health outcomes

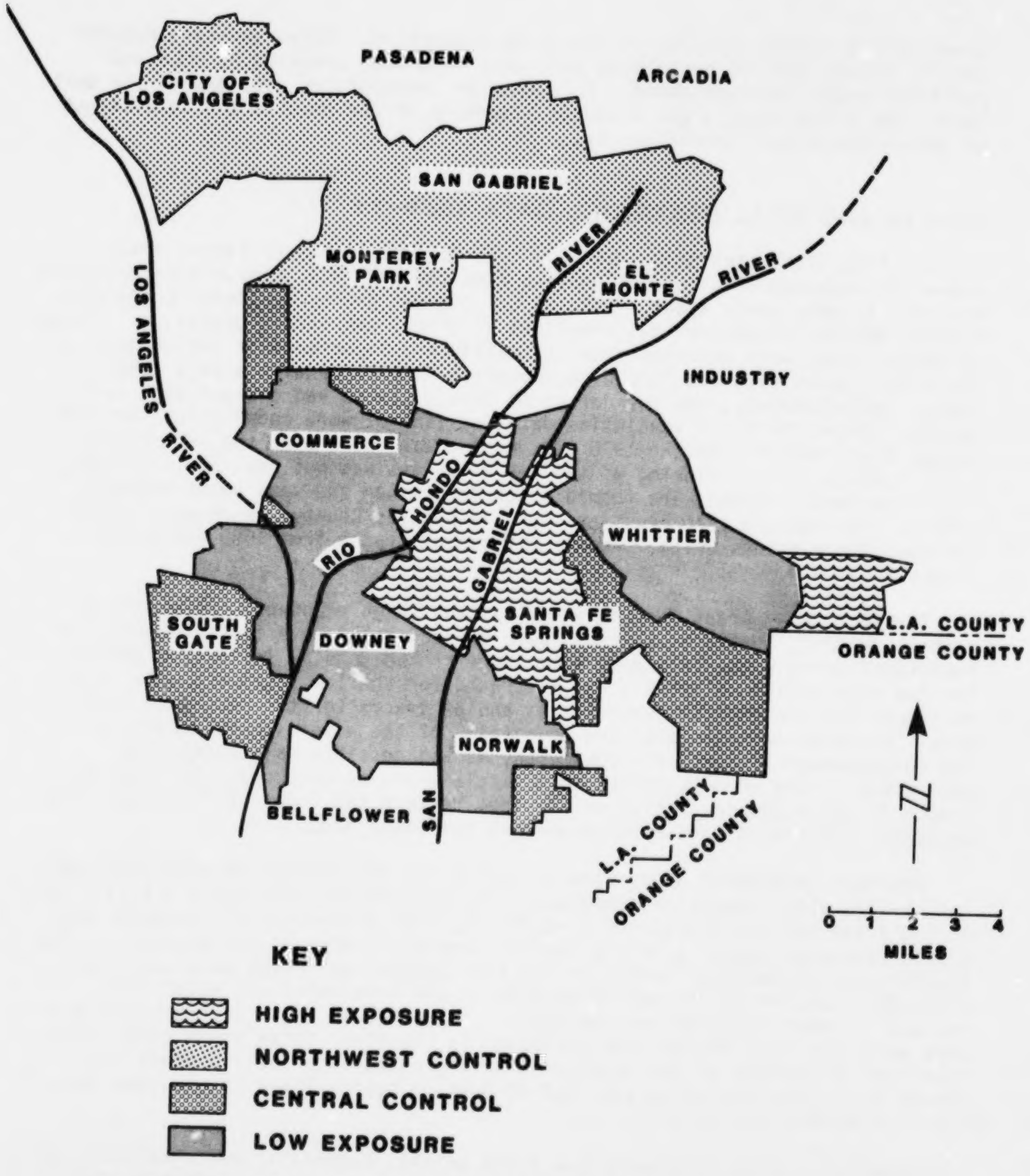


FIGURE VII-1 EPIDEMIOLOGY STUDY AREA

based on the characteristics of the study population. Three separate reports (VII-8, VII-9, VII-10) describing this work have been prepared by UCLA and published under separate cover. This chapter incorporates portions of the text taken from these reports and presents a summary of the results and conclusions of the epidemiologic investigation.

HEALTH AND VITAL STATISTICS DATA 1969-71

Existing vital statistics data for 1969-71 were linked by census tract number to area-specific population data from the 1970 U.S. Census for subsequent analysis by geographic areas. Data on Los Angeles County residents concerning births, deaths, congenital malformations at birth, and infant deaths, all listed by census tract were obtained from the California Department of Health Services. The infant death file was linked to the birth file for analysis as a cohort study. Unfortunately, the boundaries of census tracts had changed with each decade. Since the vital statistics data for 1969-71 were coded using the 1960 census tract numbers and the 1970 U.S. Census was coded with the 1970 census tract numbers, direct linking of the two data sets was not possible. Instead, "correspondence" tracts were formed which maintained the same outer boundary between the 1960 and 1970 censuses. In Los Angeles County, there were 1,159 correspondence tracts which linked 1,297 census tracts from 1960 and 1,576 tracts from 1970.

The four study areas for the investigation (high exposure, low exposure, central control, northwest control) were subsequently converted into groups of individual correspondence tracts which were broken down as follows: 21 tracts for the high reclaimed water area, 41 tracts for the low reclaimed water area, 34 tracts for the central control area and 52 tracts for the northwest control area. Although in some cases the boundaries of the water supply districts and the correspondence tracts did not match, it was possible to allocate the population living in most tracts to a single exposure category. For the few tracts in which the population was divided between two types of reclaimed water exposure, the tracts were eliminated from the study area.

The four geographic areas finally designated for evaluation were very similar in 1970 with respect to demographic characteristics (see Table VII-1). Each of the areas had few blacks and a relatively high proportion of residents with Spanish surnames and/or with the Spanish language spoken in the household. The economic and educational levels of the four population groups were comparable, although a greater percentage of persons in the high reclaimed water area resided in owner-occupied housing units. Residents in the high reclaimed water area were also less mobile than residents in the other three study areas, with less than 20 percent of the population having moved into their present residences during the preceding year and 60 percent having lived in the same house for five or more years.

Other than birth disorders (low birth weight, congenital malformations, and infant and neonatal mortality), the diseases studied were identified by number as listed by the International Classification of Diseases (ICD) - Adapted for Use in the United States (VII-11). The ICD number was based on the Eighth Revision and appeared both on the mortality and the notifiable communicable disease computer files provided by the Los Angeles County Department of Health

TABLE VII-1

GENERAL POPULATION CHARACTERISTICS FOR TWO RECLAIMED WATER AREAS AND TWO CONTROL AREAS USED FOR THE 1969-71 ANALYSES, 1970 CENSUS

Variable	Control Areas		Reclaimed Water Areas	
	Northwest	Central	Low (<5%)	High (≥5%)
General population data				
Total population	429,861	247,063	357,453	120,729
Number of males	203,767	119,169	173,591	59,456
Number of females	226,094	127,894	183,862	61,273
Persons under 18 per 100 persons 18-64 years	52.7	62.7	59.9	64.7
Persons 65 and over per 100 persons 18-64 years	19.9	14.3	13.1	9.4
Total births, 1969-71[a]	23,807	15,526	21,391	6,000
Ethnic composition				
White (%)	95.0	97.2	97.7	97.8
Spanish surname and/or language (%)	27.0	35.8	30.2	41.0
Black (%)	0.3	0.5	0.1	0.1
Other (%)	4.7	2.3	2.2	2.1
Socioeconomic status				
Percent of all families below poverty level	7.0	8.2	8.3	5.4
Percent of persons 25 and over with less than or equal to 8 years of education	21.8	27.2	25.1	20.5
Percent of occupied housing units that are renter-occupied	48.6	45.5	48.5	25.7
Percent of occupied units with 1.01 or more persons per room	7.9	12.4	11.6	12.6
Community stability				
Percent of population who moved into present residence in 1969-70	26.6	24.6	28.5	18.4
Percent of population 5 and over living in the same house as in 1965	47.6	50.9	47.4	60.2

[a] Derived from vital statistics tapes for Los Angeles County

Services and the State of California. Disease categories were selected to include all conditions that might potentially be affected by contaminants in the drinking water supply (see Table VII-2). Causes of death were combined into broad categories (e.g., diseases of the heart) because sufficient numbers of more specific conditions would not have existed on a disease-by-disease basis for small area analyses. An exception was made for death due to malignant neoplasms of the stomach, colon, rectum, and bladder, four cancer sites which have been implicated in other studies of drinking water and cancer (VII-12). The communicable diseases selected for evaluation were chosen because, historically, they have been linked to outbreaks caused by waterborne agents.

Statistical Analysis

Comparisons of populations are usually based on the occurrence of rates which allow for evaluations of groups of different sizes and for standardization of the time span of observation. However, there are other factors such as age, race, and sex, which may affect the frequency of events but which are not reflected in either the group size or span of observation.

To control for the confounding effects of multiple variables such as age and sex, the data were standardized using both the direct and indirect methods (VII-13). The direct method involved the weighting of subgroup rates for the study area (e.g., the rate among males, aged 44-54 years) by the standard population in that subgroup (i.e., the number of males, aged 44-54). In the indirect method, an expected number of events in the study area population was "predicted" based on the subgroup rates in a standard population and then compared to the observed number of events. In this investigation, the standard for the direct method was the Los Angeles County population during 1970 and, for the indirect method, a set of death- or birth-related rates for Los Angeles County during 1969-71. Since the findings of the two standardizing procedures were comparable, only the results based on the indirect method will be presented here.

Race-ethnicity was included in the standardization procedure for only a few of the health conditions evaluated. The predominant minority group in the study area was Hispanic, a group that was difficult to identify in a comparable manner from the U.S. Census and from birth or death certificates. The designation "Spanish surname" in the 1970 U.S. Census was hand-coded as such if the respondent's last name appeared on a list of approximately 8,000 "Spanish" surnames maintained by the Census Bureau. In contrast, births and deaths for Los Angeles County were coded for Spanish surnames using a computerized method available at UCLA and used by the State of California and other southwestern states (VII-14). While the results of the two coding methods were similar, they were not identical. Consequently, the use of Spanish surnames as an indicator of a separate race-ethnic group was limited to analyses of health conditions for which both the numerator and denominator were derived from the vital statistics tapes: low and very low weight births, infant and neonatal mortality, and congenital malformations.

Standardized ratios were calculated for each of the four study areas according to the following formula:

TABLE VII-2

INTERNATIONAL CLASSIFICATION OF DISEASES (ICDA), EIGHTH REVISION (1968), ADAPTED FOR USE IN THE UNITED STATES

Disease	ICDA Number
Diseases of heart	390-398,402,404,410-429
Cerebrovascular diseases (stroke)	430-438
Malignant neoplasms (cancer)	140-209
Stomach	151
Colon	153
Rectum	154.1
Bladder	188
Potential waterborne diseases	
Typhoid fever	001
Salmonellosis	003
Shigellosis	004.0-004.9
Amebiasis	006
Meningococcal infections	036
Meningitis of etiology other than mumps	045*
Meningitis of undetermined etiology	045*
Infectious hepatitis	070
Leptospirosis	100

* Classified as separate diseases by the Los Angeles County Department of Health Services

$$\text{Standardized Ratio} = \frac{\sum_{i=1}^{k} O_i}{\sum_{i=1}^{k} E_i}$$

where O = number of observed events in correspondence tract i,
E = number of expected events in correspondence tract i,
and k = number of correspondence tracts in each of the areas.

A ratio greater than 1.0 indicated that more events occurred than would have been expected, given the Los Angeles County rates, while a ratio less than 1.0 indicated that fewer events occurred than would have been expected, given the Los Angeles County rates.

The assumption was made, for each correspondence tract, that the observed number of events (O) followed a Poisson distribution with a mean equal to the expected number of events (E). The normal approximation to the Poisson distribution allowed the calculation of a standardized normal deviate for each correspondence tract according to the formula given by Armitage (VII-15):

$$Z = \frac{O - E}{\sqrt{E}}$$

Based on the series of standardized deviates in each study area, a one-way analysis of variance was used to test for differences among the four areas (VII-16).

Patterns of Mortality, 1969-1971

The findings for the various causes of death investigated are shown in Table VII-3. For deaths due to all causes, the standardized mortality ratios (SMRs), adjusted for age and sex, were less than 1.0 in each of the four study areas, indicating that there were fewer observed deaths in the areas than would have been expected based on the age- and sex-specific mortality experience of Los Angeles County. Furthermore, there was no significant difference among the four SMRs based on statistical evaluation. When considering individually the major causes of death potentially associated with exposure to waterborne contaminants (see Table VII-3), again there were no significant differences between the areas in deaths due to diseases of the heart, cerebrovascular disease (strokes), malignant neoplasms (cancer), or all other causes.

Results from the analyses of the four cancer sites (stomach, colon, rectum, bladder) of interest, are also presented in Table VII-3. There were no significant differences among the four geographical areas in any of the cited types of

TABLE VII-3

COMPARISON OF DEATHS OR ILLNESSES AMONG TWO RECLAIMED WATER AREAS AND TWO CONTROL AREAS, ADJUSTED FOR AGE AND SEX, 1969-71

Disease Category	Control Areas				Reclaimed Water Areas				Significance[b]/ P
	Northwest		Central		Low (< 5%)		High ($\geq$ 5%)		
	Number of Cases	SMR[a]/	Number of Cases	SMR[a]/	Number of Cases	SMR[a]/	Number of Cases	SMR[a]/	
Mortality (deaths)									
All causes	12,788	0.94	5,730	0.96	8,023	0.95	2,251	0.94	NS
Diseases of heart	5,068	0.94	2,170	0.97	3,151	1.01	811	0.95	NS
Cerebrovascular diseases	1,548	0.92	604	0.93	801	0.89	234	1.00	NS
Malignanat neoplasms	2,360	0.99	1,017	0.94	1,424	0.93	455	1.02	NS
of the stomach	125	1.07	55	1.08	71	1.00	24	1.19	NS
of the colon	222	0.91	100	0.96	121	0.83	33	0.83	NS
of the rectum	60	0.94	23	0.83	45	1.17	18	1.67	NS
of the bladder	68	0.99	28	0.98	40	1.01	8	0.75	NS
All other causes	3,812	0.92	1,939	0.95	2,647	0.91	751	0.86	NS
Morbidity (illnesses)									
All potential waterborne diseases	1,088	1.05	946	1.50	1,019	1.10	222	0.72	< 0.01
Infectious hepatitis	603	1.03	446	1.28	630	1.21	138	0.79	< 0.05
Shigellosis	237	1.35	277	2.53	180	1.14	38	0.74	< 0.05
Meningitis of undetermined etiology	68	0.85	61	1.22	92	1.27	21	0.86	NS
All other	180	0.91	162	1.35	117	0.68	25	0.45	< 0.01

[a] Standardized mortality or morbidity ratio; observed cases in 1969-71 divided by expected cases in 1969-71 based on Los Angeles County age - and sex-specific mortality or morbidity rates (SMR for Los Angeles County = 1.0).

[b] Level of significant difference among the four areas, one-way analysis of variance; NS = not significant ($P \geq 0.05$).

cancer. A trend was apparent for cancer of the rectum with the two reclaimed water areas displaying higher SMRs than the two control areas and the high reclaimed water area having a greater SMR than the low reclaimed water area. However, the trend was not statistically significant based on an eight percent probability that it was due to chance.

Patterns of Morbidity, 1969-71

Several communicable diseases that are routinely reported to the Los Angeles Department of Health Services were included in the analysis. These diseases, referred to here as "potential waterborne diseases" included typhoid fever, salmonellosis, shigellosis, amebiasis, meningococcal infections, meningitis of etiology other than mumps, meningitis of undetermined etiology, infectious hepatitis, and leptospirosis. Table VII-3 shows that there were significant differences among the four study areas in a category encompassing all potential waterborne diseases, infectious hepatitis, shigellosis, and the "all other" category. In none of these instances, however, were the differences in accord with the hypothesis that the disease was associated with exposure to reclaimed water. In fact, the lowest standardized morbidity ratios were observed for the high reclaimed water area.

Patterns of Birth-Associated Conditions, 1969-71

The rationale for investigating birth disorders was based on the hypothesis that if there were a harmful effect associated with the consumption of reclaimed water, intrauterine development could be impaired, resulting in lower weight or malformed infants at birth. Because weight at birth is related to the age of the mother, an adjustment was made for the mother's age in deriving standardized ratios for both low weight births (those weighing 2,500 gm or less) and very low weight births (those weighing 1,500 gm or less). As shown in Table VII-4, there were no significant differences among the four study areas in the standardized ratios for either low or very low weight births. Furthermore, since all of the ratios were less than 1.0, it was concluded that the four regions had fewer low or very low weight births than would be expected based on the Los Angeles County maternal age-specific rates. A further adjustment of the standardized ratios for the race-ethnic category of the mother resulted in similar findings.

The occurrence of congenital malformations, in contrast to low weight births, did differ significantly between the four study areas. Standardized ratios of congenital malformations, adjusted for age of mother and birth weight, are shown in Table VII-4. A higher than expected number of congenital malformations was observed only in the northwest control area while the other three areas, including the reclaimed water areas, showed either the same or slightly fewer reported congenital malformations than would be expected based on maternal age- and birth weight-specific congenital malformation rates for Los Angeles County. When further adjusted for race-ethnicity, the standardized ratios in all four areas increased slightly (northwest control = 1.24, central control = 0.83, low reclaimed water = 1.06, and high reclaimed water = 1.12), although the significant difference ($P = 0.005$) was due primarily to the increase in the northwest control and the decrease in the central control.

TABLE VII-4

COMPARISON OF BIRTH OUTCOMES OR DEATHS DURING THE FIRST YEAR OF LIFE AMONG TWO RECLAIMED WATER AREAS AND TWO CONTROL AREAS, 1969-71

	Control Areas				Reclaimed Water Areas				
	Northwest		Central		Low (< 5%)		High (≥ 5%)		
	Number of Events	SR[a]/	Number of Events	SR[a]/	Number of Events	SR[a]/	Number of Events	SR[a]/	Significance[b]/ P
Birth Outcomes									
Low weight births	1,389	0.82	950	0.85	1,344	0.87	330	0.76	NS
Very low weight births	179	0.75	118	0.75	214	0.98	61	0.99	NS
Congenital malformations	277	1.17	117	0.77	212	1.01	61	1.03	< 0.01
Death Outcomes									
Infant deaths	347	1.01	240	1.05	358	1.04	87	0.92	NS
Neonatal deaths	260	1.07	180	1.12	268	1.07	67	0.97	NS

a/ Standardized ratios; observed events in 1969-71 divided by expected events in 1969-71 based on Los Angeles County age of mother-specific rates of birth outcomes or age of mother-and birth weight-specific rates of death outcomes (SR for Los Angeles County = 1.0).

b/ Level of significant difference among the four areas, one-way analysis of variance; NS = not significant ($P \geq 0.05$).

Patterns of Infant Mortality, 1969-71

The final analysis focused on deaths occurring among those infants born during 1969-71 to residents of the four study areas. Because both age of the mother and the weight of the infant at birth have an effect on mortality rates during the first year of life, the mortality data were adjusted for the confounding effects of these two variables. As presented in Table VII-4, the standardized ratios for both infant deaths (less than one year) and neonatal deaths (under 28 days) in the four areas tended to be slightly greater than in Los Angeles County as a whole, with the exception of the high reclaimed water area which had slightly fewer infant and neonatal deaths than expected based on Los Angeles County rates. Among the four areas, however, there were no significant differences in the occurrence of either infant or neonatal deaths.

HEALTH AND VITAL STATISTICS DATA 1972-78

To maintain continuity with the 1969-71 analyses, the study areas were again defined by correspondence tracts even though all of the 1972-78 data were coded with 1970 Census tract numbers. Data on Los Angeles County residents concerning births, deaths, congenital malformations at birth (only through 1977) and infant deaths, all originally or subsequently coded with census tract numbers, were provided by the California Department of Health Services. The infant death file was linked by year to the birth file for analysis as a cohort study.

The boundaries of the high and low reclaimed water areas used in the 1969-71 analyses were retained in the 1972-78 analyses. As indicated in Figure VII-2, the percentage of reclaimed water supplied to the areas had increased considerably during the period of study. By the mid-1970s the amount of reclaimed water in domestic supplies had increased to nearly 16 percent in the high exposure area and to six percent in the low exposure area.

The boundaries of the "northwest" control area also remained unchanged for the 1972-78 analyses; this was not the case, however, for the central control area. After 1971, persons residing in 20 of the 34 correspondence tracts in the central control area were receiving a measurable proportion of reclaimed water. Consequently, the central control area was redefined to contain 14 correspondence tracts, the residents of which received no reclaimed water during the 1960s and 1970s. The geographic location of the four study areas is shown in Figure VII-3. Despite the reduction of population in the central control area, the four areas were very similar in terms of their demographic characteristics as indicated in Table VII-5, with each area having few blacks and a relatively high proportion of residents with Spanish surnames and/or the Spanish language spoken at home.

With the exception of birth disorders, the health conditions evaluated using the 1972-78 data sets were again classified according to the 1968 version of the ICD system (VII-11). However, the previously evaluated health conditions listed in Table VII-3 were somewhat modified for the 1972-78 analyses. The same mortality conditions were assessed, but some changes were made in the evaluation of infectious diseases. Shigellosis and infectious hepatitis (designated in the 1972-78 data set as hepatitis A) were the only diseases to be evaluated individ-

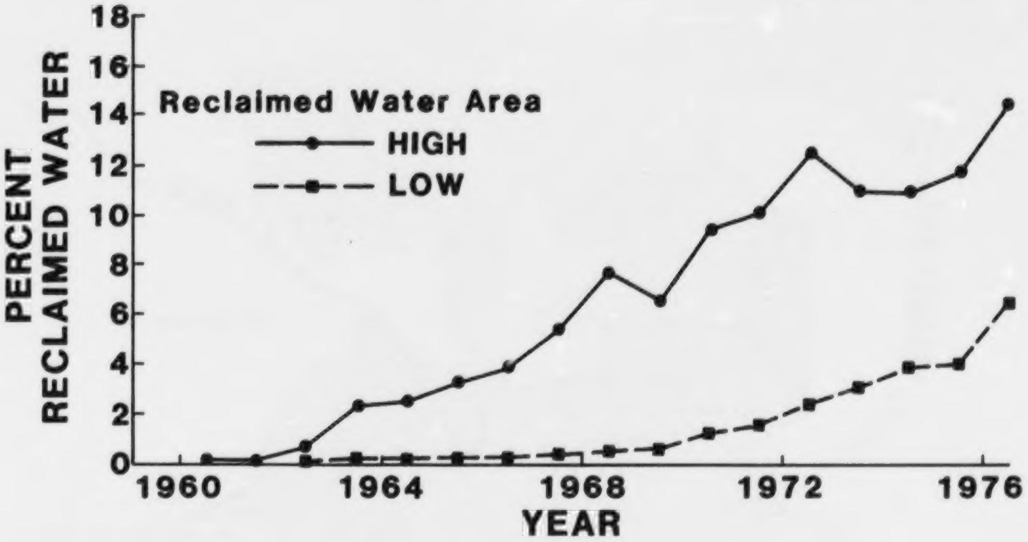


FIGURE VII-2 PERCENTAGE OF RECLAIMED WATER BY EXPOSURE AREA AND YEAR

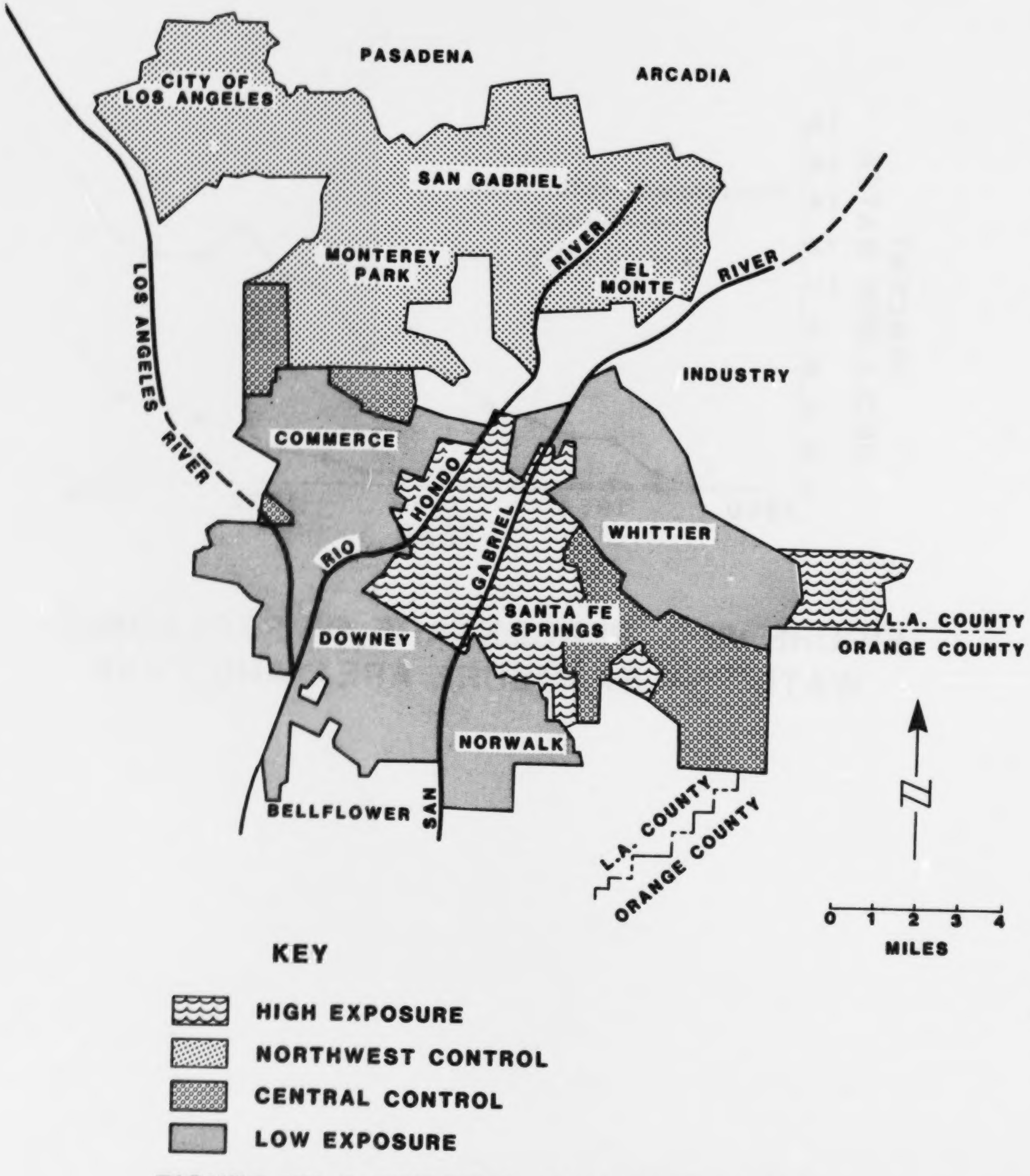


FIGURE VII-3 EPIDEMIOLOGY STUDY AREA VITAL STATISTICS ANALYSES 1972-78

TABLE VII-5

GENERAL POPULATION CHARACTERISTICS FOR TWO RECLAIMED WATER AREAS AND TWO CONTROL AREAS USED FOR THE 1972-78 ANALYSES, 1970 CENSUS

Variable	Control Areas		Reclaimed Water Areas	
	Northwest	Central	Low (<5%)	High (≥5%)
General Population Data				
Total population	429,861	122,474	357,453	120,729
Number of males	203,767	59,777	173,591	59,456
Number of females	226,094	62,697	183,862	61,273
Persons under 18 per 100 persons aged 18-64 years	52.7	67.9	59.9	64.7
Persons 65 and over per 100 persons aged 18-64 years	19.9	10.9	13.1	9.4
Ethnic Composition				
White (%)	95.0	96.7	97.7	97.8
Spanish surname and/or language (%)	27.0	38.8	30.2	41.0
Black (%)	0.3	0.7	0.1	0.1
Other (%)	4.7	2.6	2.2	2.1

ually. All potential waterborne diseases were again evaluated as a single category. In addition, incident cancer cases for malignant neoplasms of the stomach, colon, rectum, and bladder were evaluated. These data were obtained from the Los Angeles County--University of Southern California Comprehensive Cancer Center. Personnel of the Cancer Center actively review hospital pathology reports and death certificates for evidence of cancer. The Cancer Center covers 182 of 183 hospitals in Los Angeles County and several hospitals located in adjacent counties. Cases registered by the Cancer Center are limited to those with pathological evidence of cancer listed on a hospital pathology report, and those with cancer listed on the death certificate. Thus, those individuals with clinical disease, but no pathologic evidence of cancer, and those for whom the diagnosis of cancer is unavailable when the death certificate is completed, may not be included in the registry. The number of cases missed, however, is believed to be small (VII-17).

Statistical Analysis

The 1972-78 analysis differed from the previous analysis in that there were no accurate census data on the population at risk to use in comparing morbidity and mortality outcomes. The 1970 U.S. Census was conducted between two and eight years before collection of the data set. Because the size and demographic complexion of the study populations might well have changed considerably over the years, comparisons of mortality outcomes and cancer incidence were based on proportionate ratios. Mortality ratios were adjusted either by the direct or the indirect methods for the potential confounding effects of age and sex while incidence ratios were adjusted for age, sex and race. For morbidity data, rather than using proportionate ratios, the incidence of potential waterborne diseases was calculated as a percentage of the 1969-71 average number of reported cases. Lack of population data did not affect those analyses which defined the population at risk as total births (infant and neonatal mortality, low and very low birth weights, and congenital malformations). Standardized mortality and morbidity ratios, adjusted indirectly for maternal age, birth weight, and race, were used for comparison of those health outcomes.

The evaluations of the 1972-78 data were expanded to consider temporal trends as well as overall comparisons among the four study areas. Two statistical techniques, weighted linear regression and analysis of covariance were used in the evaluations of both the death and birth related outcomes.

Adjusted Proportionate Mortality Ratios (APMRs). To facilitate a comparison of cause-specific mortality experience in the absence of information on the population at risk, a proportionate mortality ratio was calculated for each of the four study areas using the direct method of adjustment. This method was used for each of four cause-of-death categories: heart disease, cerebrovascular disease, cancer, and all other causes.

For each year from 1972 to 1978, age-, sex-specific proportions were calculated for each of the four study areas. Those specific proportions were then applied to the age-, sex-specific subgroups in an arbitrarily chosen standard (in this case all deaths among Los Angeles County residents in 1975) to generate the expected deaths due to a specific cause. The number of expected deaths divided by the total number of deaths due to all causes in the standard resulted in the adjusted proportion as follows:

$$\text{APMR} = \frac{\sum_{i=1}^{n} D_i \left(\frac{d_{ij}}{d_i}\right)}{D}$$

where d_{ij} = number of deaths due to cause j in the ith age-, sex-specific subgroup of the study area;

d_i = total number of deaths in the ith age-, sex-specific subgroup of the study area;

D_i = total number of deaths in the ith age-, sex-specific subgroup of the standard;

D = total number of deaths for all subgroups in the standard;

and n = the total number of age-, sex-specific subgroups in the population.

The variance of this statistic was estimated according to the formula based on work previously published by Chiang (VII-18).

Standardized Proportionate Mortality Ratios (SPMRs). For the rare causes of death such as malignant neoplasms of the stomach, colon, rectum, and bladder, the age-, sex-specific proportions of death in the study populations were too unstable to serve as an effective means for standardizing the data. The proportions of death due to these cancers were adjusted, therefore, by the indirect method.

The Poisson distribution has been used to test the hypothesis that an observed number of deaths due to a rare cause is not improbably large by assuming some parametric value for the expected number of deaths (VII-19). When no information is available on the size of the population at risk, the expected number of deaths can be estimated by applying age- and sex-specific proportionate mortality ratios for a specific cause of death from a comparison population to the age and sex subgroups of deaths occurring in the population of interest. The ratio of observed deaths to expected deaths is the standardized proportionate mortality ratio (SPMR) which can be expressed as:

$$\text{SPMR} = \frac{O}{E}$$

where O = number of observed deaths in the study population;

and E = number of expected deaths in the study population based on the age- and sex-specific proportionate mortality ratios in a set of deaths which serves as a standard.

The expected number of deaths used in the equation can be described in more detail as follows:

$$\text{Expected number of deaths} = \sum_{i=1}^{n} d_i \left(\frac{D_{ij}}{D_i}\right)$$

where d_i = total number of deaths in the ith age-, sex-specific subgroup of the population of interest,

D_{ij} = number of deaths in the ith age-, sex-specific subgroup due to cause j of the comparison population,

D_i = total number of deaths in the ith age-, sex-specific subgroup of the comparison population

and n = the total number of age-, sex-specific subgroups in the population.

The assumption was made that the observed number of deaths followed a Poisson distribution with the mean equal to the expected number of deaths.

For each year from 1972 to 1978, the expected number of deaths was calculated for malignant neoplasms of the stomach, colon, rectum, and bladder, based on the combined proportionate mortality experience of the northwest and central control areas for a given year. The probability that more than the observed number of deaths due to each malignant neoplasm would occur was estimated separately for each of the seven years and then combined into a single probability using the method described by Rao (VII-20).

If the mortality experience in the exposed areas was exactly like that in the combined control areas, the SPMR would be 1.0; more excess deaths than expected would result in an SPMR greater than 1.0, possibly indicating an association between exposure and disease. Since the focus of these analyses was on excess death, the high exposure area and low exposure area SPMRs were tested for statistical significance using a one-sided test.

Standardized Proportionate Incidence Ratios (SPIRs). Data obtained for incident cases of cancer among residents of the study areas diagnosed between 1972 and 1978 (VII-21) were analyzed using standardized proportionate incidence ratios. SPIRs were calculated for malignant neoplasms of the stomach, colon, rectum and bladder in each of the four study areas, for years 1972-78, by dividing the observed number of cases by the expected number of cases as follows:

$$\text{SPIR} = \frac{O}{E}$$

where O = number of observed cancer cases (specified site) in the study population, and E = number of expected cancer cases (specified site) in the study population based on age-, sex-, and race-specific proportionate incidence ratios in the standard.

The expected number of cancer cases used in the equation can be described in more detail as follows:

$$\text{Expected number of cancer cases} = \sum_{i=1}^{n} c_i \left(\frac{C_{ij}}{C_i}\right)$$

where c_i = total number of cancer cases (all sites) in the ith age-, sex-, race-specific subgroup of the study population,
C_{ij} = number of cases of cancer at site j in the the ith age-, sex-, race-specific subgroup of the study population.
C_i = total number of cancer cases (all sites) in the ith age-, sex-, race-specific subgroup of the standard population,
and n = the number of age-, sex-, race-specific subgroups.

The total number of cancer cases (all sites), c_i and C_i, includes all cancers except cervical carcinoma-in-situ and melanomas; skin cancers are included in cancer cases (all sites). The cancer site was coded by the Cancer Center using the International Classification of Diseases, Adapted (ICDA), Eighth Revision (VII-11).

For each year from 1972 to 1978, site-specific proportions were calculated for each age-, sex-, and race-specific subgroup in tne standard population, Los Angeles County. This procedure yielded four sets of proportions, one for each of the four cancer sites: stomach, colon, rectum, and bladder. Each set of proportions was applied to the total number of cancers (all sites) occurring in the age-, sex-, and race-specific subgroups of the four study areas to generate the expected number of site-specific cancers. The subgroups used in the adjustment procedure were defined by eight age groups (10-year categories), two racial groups (white and black), and two sexes. Cancers occurring in individuals of races other than black or white were excluded from the calculation of the SPIRs.

Standardized Ratios (SR) for Birth-Related Outcomes. As in the 1969-71 analyses, standardized ratios were used to evaluate the following birth-related events: low and very low weight birth, neonatal mortality, infant mortality, and congenital malformations. For the 1972-78 data, standardized ratios adjusted for the potential confounding effects of maternal age, birth weight, and race were derived for each year according to the equation described in the 1969-71 statistical methods section (VII-8). The expected number of events for the birth related outcomes was based on the 1969-71 Los Angeles County rates. If the standardized ratio was greater than 1.0, the health outcome was more common than expected, suggesting a possible association between exposure and birth related events.

Weighted Linear Regression. The occurrence of temporal trends in the various mortality, cancer incidence, or birth-related indices was analyzed by a linear regression technique which assessed the relationship between a health outcome measure (either an adjusted proportionate mortality ratio, a standardized proportionate incidence ratio, or a birth related standardized ratio) and the year of occurrence. A least squares regression line (VII-22) was fitted to the APMRs, SPIRs, and SRs for each of the four study areas; evidence of a temporal trend existed when the slope was different from zero. However, the slopes of the lines were also compared to determine differential temporal trends among the individual areas by calculating 95 percent confidence intervals for each slope estimate (VII-23). Overlap of the confidence intervals indicated no statistically significant differences among the slopes ($P > 0.05$).

Weighted linear regression analyses were also conducted for two combined areas, formed by collapsing the boundaries of the original four study areas and redrawing boundaries according to the presence or absence of exposure to reclaimed water. The dichotomous grouping (high and low exposure areas = the combined exposure area; central and northwest control areas = the combined control area) yielded more stable trends for comparison given the population size, and potentially improved the likelihood of detecting an effect due to exposure.

Analysis of Covariance. Because it was likely that the temporal trends among the adjusted proportionate mortality ratios, standardized proportionate incidence ratios, and birth related standardized ratios of the four study areas would be equivalent, some overall comparison of the areas was required. Analysis of covariance enabled such an evaluation by holding the effect of a covariate (in this case time) constant and then comparing the groups to determine if they were significantly different (VII-22). In addition to covariance analyses of the four study areas, analyses were conducted for the combined exposed and combined control areas.

Patterns of Mortality, 1972-78

For evaluation of mortality patterns, data were expressed as adjusted proportions of all death due to a specific cause. If a contaminant in the drinking water had increased the death rate due to a specific cause, and the death rate due to all causes had remained constant, the proportion of all death due to that specific cause would have increased over the course of time. This hypothesis implicitly assumed that: 1) the total rate of mortality was equivalent among the four study areas over time and 2) waterborne contaminants were related to only certain causes of death rather than all causes of death. Trends over time were evaluated by weighted linear regression. Linear slope estimates were bracketed by 95 percent confidence intervals, with significance between slopes determined by non-overlapping of the confidence intervals. Differences among the adjusted proportions of death were determined by analysis of covariance.

As indicated in Figure VII-4, the total number of deaths occurring in each year between 1972-78 compared to the average number of deaths for 1969-71, changed very little in each of the four study areas during the 1970s. There were also no upward or downward trends over time, suggesting that total deaths would provide a stable denominator for calculating proportionate mortality ratios for the major causes of death evaluated, including death due to heart disease, cerebrovascular disease, cancer, and all other causes. Plots of proportionate mortality ratios over time for these health outcomes have been included in Appendix O.

For deaths due to heart disease, there was a slight downward trend in three of the four study areas as indicated by the negative slope estimates shown in Table VII-6. The slopes of the linear regressions for the high exposure area and northwest control area were significantly different since the confidence intervals surrounding the estimated slopes did not overlap. However, when comparing the combined exposure areas and the combined control areas, the 95 percent confidence intervals did overlap indicating that there were no significant differences among the adjusted proportionate mortality ratios for the four study areas and the combined areas based on analysis of covariance (see Table VII-7).

The findings for deaths due to cerebrovascular disease, malignant neoplasms, and all other causes of death are shown in Tables VII-6 and VII-7. Again, there were no significant differences in temporal trends among the four study areas and combined exposed and combined control areas, nor were there significant differences in the proportions of deaths due to the various causes.

For deaths due to specific cancers, statistical analyses were not conducted to determine temporal trends. Instead, standardized proportionate mortality ratios adjusted for age and sex were derived for the high and low exposure areas using the combined control areas as the standard. Graphs depicting the SPMRs versus time have been included in Appendix O. Averaged SPMRs for cancers of the stomach and colon, shown in Table VII-8, were less than 1.0, indicating that there were less observed deaths in the high and low exposure areas than would have been expected based on the age- and sex-specific proportions of death in the combined control areas. Furthermore, neither area had significantly greater levels of either stomach or colon cancer deaths than expected based on statistical evaluation.

For cancer of the rectum (see Table VII-8) the low reclaimed water area tended to have slightly fewer deaths than expected while the high exposure area tended to have more deaths than expected. The excess deaths in the high exposure area were significantly greater than expected based on the rectal cancer mortality experience in the combined control areas ($P = 0.03$). However, when evaluating the pattern of mortality during the seven years of observation, (see Figure VII-5), the SPMRs varied considerably and did not follow a dose response relationship, i.e., a continued increase in the number of excess deaths in both the high and low reclaimed water areas, with the greatest increase expected in the high reclaimed water area.

For cancer of the bladder, the low reclaimed water area again tended to have fewer deaths than expected ($SPMR < 1.0$) based on the combined experience of the two control areas while the high reclaimed area had more deaths than expected

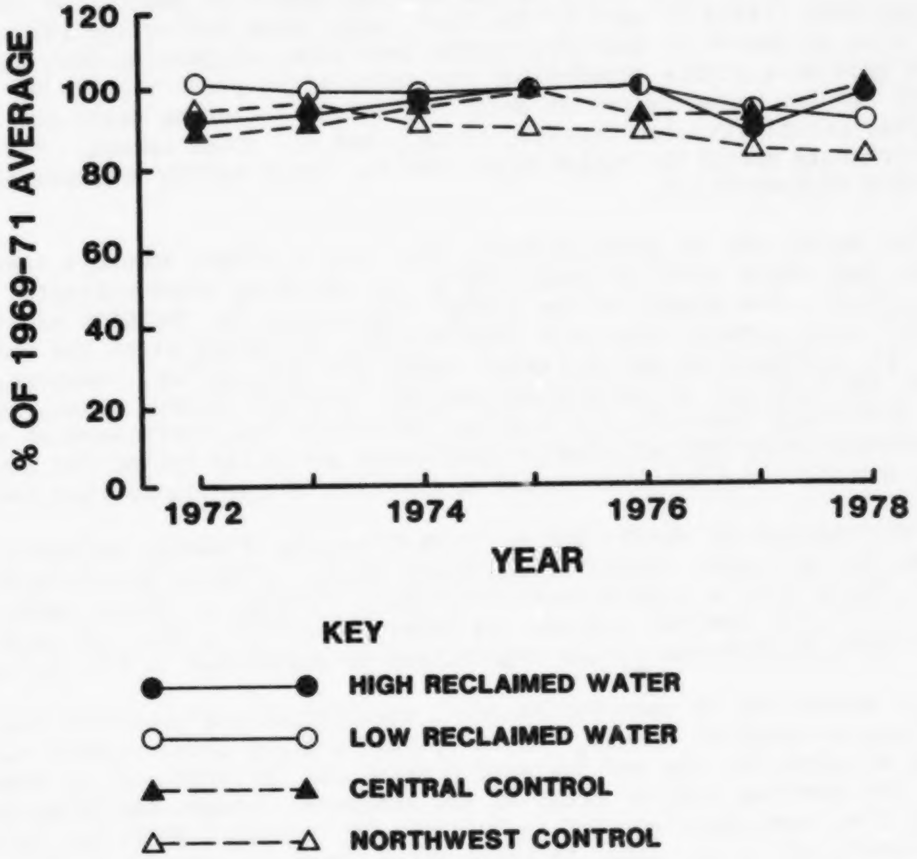


FIGURE VII-4

1972-78 DEATHS DUE TO ALL CAUSES,
AS PERCENTAGE OF AVERAGE 1969-71 DEATHS

TABLE VII-6

COMPARISONS OF SECULAR TRENDS OF DEATH AMONG RECLAIMED WATER AREAS AND CONTROL AREAS, ADJUSTED FOR AGE AND SEX, 1972-78

	Diseases of Heart		Cerebrovascular Diseases		Malignant Neoplasms		All Other Causes	
Geographic Area	Slope[a]	95% Confidence Interval[b]	Slope[a]	95% Confidence Interval[b]	Slope[a]	95% Confidence Interval[b]	Slope[a]	95% Confidence Interval[b]
Reclaimed water areas								
Low (<5%)	-0.002	(-0.008, 0.004)[c]	-0.004	(-0.006, -0.002)[d]	0.004	(0.000, 0.008)[d]	0.002	(-0.001, 0.005)[d]
High ($\geq$ 5%)	0.006	(-0.000, 0.012)[c]	-0.006	(-0.010, -0.003)[d]	0.002	(-0.004, 0.008)[d]	-0.002	(-0.007, 0.004)[d]
Combined water areas	-0.000	(-0.006, 0.005)[e]	-0.005	(-0.007, -0.003)[e]	0.004	(0.001, 0.007)[e]	0.001	(-0.003, 0.004)[e]
Control areas								
Northwest	-0.004	(-0.007, -0.001)[c]	-0.003	(-0.005, -0.002)[d]	0.005	(0.003, 0.008)[d]	0.002	(-0.001, 0.005)[d]
Central	-0.003	(-0.014, 0.007)[c]	-0.004	(-0.010, 0.003)[d]	0.003	(-0.005, 0.011)[d]	0.004	(-0.001, 0.010)[d]
Combined control areas	-0.004	(-0.007, -0.002)[e]	-0.003	(-0.005, -0.002)[e]	0.005	(0.003, 0.008)[e]	0.002	(-0.001, 0.005)[e]

[a] Derived from weighted linear regression of adjusted proportionate mortality ratios (APMRs) for health outcomes on year (1972 = 1,..., 1978 = 7).

[b] Interval around slope = SLOPE ± 1.96 [STANDARD ERROR OF SLOPE].

[c] No significant differences among the four areas based on overlapping 95% confidence intervals, with the exception of the high reclaimed water area and the northwest control area.

[d] No significant difference among the four areas based on overlapping 95% confidence intervals.

[e] No significant difference between the combined reclaimed water areas and the combined control areas based on overlapping 95% confidence intervals.

TABLE VII-7
COMPARISONS OF DEATH AMONG RECLAIMED WATER AREAS AND CONTROL AREAS, ADJUSTED FOR AGE AND SEX, 1972-78

	Control Areas				Reclaimed Water Areas					Combined Areas				
	Northwest		Central		Low (< 5%)		High (≥ 5%)			Control		Reclaimed		
Mortality Category	Number of Events	APMR[a]/	Number of Events	APMR[a]/	Number of Events	APMR[a]/	Number of Events	APMR[a]/	Significance[b]/ P	Number of Events	APMR[a]/	Number of Events	APMR[a]/	Significance[c]/ P
Diseases of the heart	11,232	0.398	1,958	0.393	7,206	0.403	1,945	0.399	NS	13,190	0.397	9,151	0.402	NS
Cerebrovascular diseases	3,049	0.104	497	0.102	1,704	0.097	447	0.096	NS	3,546	0.104	2,151	0.097	0.03
Malignant neoplasms	5,205	0.199	1,080	0.204	3,634	0.197	1,120	0.213	NS	6,285	0.200	4,754	0.200	NS
All other causes	7,327	0.298	1,639	0.301	5,752	0.303	1,533	0.292	NS	8,966	0.298	7,285	0.300	NS

a/ Direct adjusted proportionate mortality ratio based on 1975 Los Angeles County deaths as standard (Los Angeles County APMR due to heart disease = 0.383, APMR due to cerebrovascular disease = 0.110, APMR due to malignant neoplasm = 0.200, APMR due to all other causes = 0.307).

b/ Level of significant difference among the four areas, analysis of covariance; NS = not significant ($P \geq 0.05$).

c/ Level of significant difference between the combined reclaimed water areas and combined control areas, analysis of covariance; NS = not significant ($P \geq 0.05$).

TABLE VII-8

COMPARISON OF DEATH DUE TO SPECIFIC MALIGNANT NEOPLASMS AMONG TWO RECLAIMED WATER AREAS AND COMBINED CONTROL AREAS, ADJUSTED FOR AGE AND SEX, 1972-78

	High (≥ 5%) Reclaimed Water Area			Low (< 5%) Reclaimed Water Area		
Mortality Category	Number of Cases 1972-78	SPMR[a] 1972-78	Significance[b] P	Number of Cases 1972-78	SPMR[a] 1972-78	Significance[b] P
Malignant neoplasm of the stomach	45	0.98	NS	156	0.95	NS
of the colon	107	0.97	NS	302	0.76	NS
of the rectum	26	1.27	0.03	70	0.95	NS
of the bladder	28	1.12	NS	90	0.97	NS

[a] Average standardized proportionate mortality ratio; observed deaths in 1972-78 divided by expected deaths in 1972-78 based on the 1972-78 age-, sex-specific proportionate mortality ratios of the combined control areas (SPMR for combined control = 1.0).

[b] Level of significant difference between observed and expected, one-sided test; NS = not significant (P ≥ 0.05).

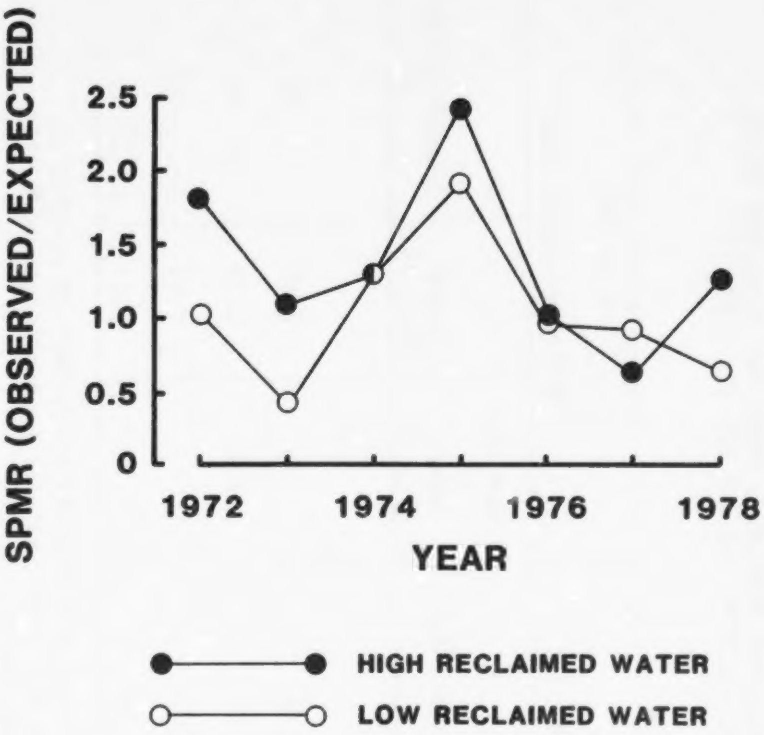


FIGURE VII-5
STANDARDIZED PROPORTIONATE
MORTALITY RATIOS (SPMR's)
ADJUSTED FOR AGE AND SEX
MALIGNANT NEOPLASM OF RECTUM 1972-78

(SPMR > 1.0) as indicated in Table VII-8. The excess in deaths, however, was not significantly greater than expected using the conventional level of P = 0.05 as the deciding criterion.

Patterns of Cancer Incidence, 1972-78

For evaluation of cancer incidence patterns, data were expressed as standardized proportionate incidence ratios for each of four malignant neoplasms: stomach, colon, rectum, and bladder. An adjustment was made to control for study area differences in the age at diagnosis of the cancer, and both the sex and race of the cancer patient. Trends over time were evaluated by weighted linear regression. Linear slope estimates were bracketed by 95 percent confidence intervals, with significance between slopes determined by non-overlapping of the confidence intervals. Differences among the standardized proportionate incidence ratios were determined by analysis of covariance. Plots of SPIRs over time for each malignant neoplasm have been included in Appendix O.

When considering the secular trends of stomach cancer incidence over time, the results of the weighted linear regression analysis (see Table VII-9) showed no difference among the four study areas since the confidence intervals surrounding the estimated slopes did not overlap. The same was true when comparing the combined reclaimed water areas and the combined control areas. In addition, none of the linear slopes were significantly different from zero, suggesting that there was no change in the proportion of all cancers due to cancer of the stomach during the years 1972-78. Based on the analysis of covariance, there were no significant differences among the four study areas or combined reclaimed water and control areas in the proportionate incidence ratios. These results are presented in Table VII-10.

For malignant neoplasm of the colon, three out of the four areas exhibited no differences in slope (Table VII-9). There was a difference in the slope between the low and high reclaimed water areas, with the latter having a slight downward trend over time. As shown in Table VII-10, there was no significant difference among the four study areas in the levels of the SPIRs after controlling for the covariate, time. There was, however, a difference between the combined reclaimed water areas and the combined control areas, with the latter having slightly more observed incident cases than expected based on the proportionate distribution of colon cancer cases in Los Angeles County.

The results of the weighted linear regression and covariance analysis for malignant neoplasm of the rectum are shown in Tables VII-9 and VII-10. In both sets of analyses, there was no significant difference observed either among the four areas or between the combined reclaimed water areas and the combined control areas.

For the final incident cancer, malignant neoplasm of the bladder, there was no difference observed in the slopes of the four study areas or combined areas as shown in Table VII-9. Furthermore, based on the analysis of covariance (Table VII-10), there were no statistically significant differences among the four areas or combined areas in the proportionate incidence of bladder cancer.

TABLE VII-9

COMPARISON OF SECULAR TRENDS OF CANCER INCIDENCE AMONG RECLAIMED WATER AREAS AND CONTROL AREAS, ADJUSTED FOR AGE, SEX, AND RACE, 1972-78

Geographic Area	Malignant Neoplasm of the Stomach		Malignant Neoplasm of the Colon		Malignant Neoplasm of the Rectum		Malignant Neoplasm of the Bladder	
	Slope a/	95% Confidence Interval b/	Slope a/	95% Confidence Interval b/	Slope a/	95% Confidence Interval b/	Slope a/	95% Confidence Interval b/
Reclaimed water areas								
Low (< 5%)	0.017	(-0.024,0.058) c/	0.028	(-0.005,0.061) e/	0.024	(-0.060,0.108) c/	0.021	(-0.028,0.070) c/
High (≥ 5%)	0.007	(-0.066,0.080) c/	-0.051	(-0.090,-0.012) e/	-0.052	(-0.193,0.089) c/	-0.004	(-0.075,0.067) c/
Combined water areas	0.015	(-0.018,0.048) d/	0.010	(-0.019,0.039) d/	0.009	(-0.058,0.076) d/	0.015	(-0.022,0.052) d/
Control areas								
Northwest	-0.050	(-0.101,0.001) c/	-0.003	(-0.042,0.036) e/	-0.009	(-0.044,0.026) c/	-0.020	(-0.051,0.011) c/
Central	-0.041	(-0.164,0.082) c/	-0.013	(-0.103,0.077) e/	-0.050	(-0.091,-0.009) c/	-0.058	(-0.150,0.038) c/
Combined control areas	-0.049	(-0.094,-0.004) d/	-0.005	(-0.038,0.028) d/	-0.016	(-0.041,0.009) d/	-0.026	(-0.057,0.005) d/

a/ Derived from weighted linear regression of standardized proportionate incidence ratios (SPIRs) for specific cancers on year (1972=1,...1978=7).
b/ Interval around slope = SLOPE ± 1.96 [STANDARD ERROR OF SLOPE].
c/ No significant differences among the four areas based on overlapping 95% confidence intervals.
d/ No significant difference between the combined reclaimed water areas and the combined control areas based on overlapping 95% confidence intervals.
e/ No significant differences among the four areas based on overlapping 95% confidence intervals, with the exception of the high reclaimed water area and low reclaimed water area.

TABLE VII-10

COMPARISON OF CANCER INCIDENCE AMONG RECLAIMED WATER AREAS AND CONTROL AREAS, ADJUSTED FOR AGE, RACE, AND SEX, 1972-78

Cancer Incidence Category	Control Areas				Reclaimed Water Areas				Significance b/ P	Combined Areas				Significance c/ P
	Northwest		Central		Low (< 5%)		High (≥ 5%)			Control		Reclaimed		
	Number of Events	SPIR a/	Number of Events	SPIR a/	Number of Events	SPIR a/	Number of Events	SPIR a/		Number of Events	SPIR a/	Number of Events	SPIR a/	
Malignant neoplasm of the stomach	287	0.97	79	1.10	216	1.03	65	0.99	NS	366	1.00	281	1.02	NS
Malignant neoplasm of the colon	1,039	1.07	211	1.08	623	0.97	181	0.96	NS	1,250	1.07	804	0.97	0.03
Malignant neoplasm of the rectum	461	1.06	95	1.02	309	1.02	101	1.11	NS	556	1.05	410	1.04	NS
Malignant neoplasm of the bladder	451	0.94	98	0.98	218	0.95	94	0.94	NS	549	0.95	312	0.95	NS

a/ Standardized proportionate incidence ratio; observed incident cases of cancer in 1972-78 divided by the expected number of incident cases of cancer based on the 1972-78 age-, sex-, and race-specific proportions in Los Angeles County (SPIR for Los Angeles County = 1.0).

b/ Level of significant difference among the four areas, analysis of covariance; NS = not significant ($P \geq 0.05$).

c/ Level of significant difference between the combined reclaimed water areas and combined control areas; analysis of covariance; NS = not significant ($P \geq 0.05$).

Patterns of Morbidity, 1972-78

The number of potential waterborne diseases remained relatively constant in each of the four study areas over the course of the seven years of the evaluation. Figure VII-6 presents temporal trends for all potential waterborne diseases, shigellosis, and hepatitis A consisting of the relative number of cases per year expressed as a percentage of the average number of cases in 1969-71. For all potential waterborne diseases combined, there was a slight relative increase in the high exposure area for a few years which thereafter settled down to a pattern similar to the other three areas. For shigella infections, there was a relative increase over the 1969-71 average in all four areas with the high exposure area again showing a higher rate for a few years which eventually became indistinguishable from the other three areas. Finally, for hepatitis A, there tended to be an excess in the high reclaimed water area over the other three areas, yet all four areas demonstrated a relative decline in the occurrence of reported hepatitis A during the period of the investigation.

Patterns of Birth Associated Conditions, 1972-78

Standardized ratios, adjusted for maternal age were derived for low weight births ($\leq$ 2,500 gm) and very low weight births ($\leq$ 1,500 gm) using births among residents of Los Angeles County as the standard population. Standardized ratios greater than 1.0 signified the occurrence of more events than expected based on the standard. SRs were statistically compared to detect differences between the four study areas and the combined exposed areas and combined control areas over time (plots of standardized morbidity ratios versus time have been included in Appendix O). Standardized ratios were also compared in terms of magnitude by holding time as a constant factor.

The results of the linear regression analyses for low and very low weight births are presented in Table VII-11. While some of the slopes were positive and some were negative, there were no significant differences among the four areas or combined water areas based on overlapping 95 percent confidence intervals. While the standardized low weight birth and very low weight birth ratios tended to be considerably less than expected (SR $<$ 1.0) as indicatd in Table VII-12, there was a statistically significant difference among the four areas. However, the direction of the difference was not in accord with the hypothesis that the occurrence of low birth weight in infants is associated with the consumption of reclaimed water. For the combined area analysis, the SRs for the exposed areas were higher than the SRs for the control areas, but the differences were not statistically significant. These results did not change appreciably when also adjusted for the potentially confounding effects of race.

The standard ratios derived for congenital malformations at birth were adjusted for both maternal age and infant birth weight (see Appendix O). The standard was again based on data from Los Angeles County for 1969-71. In this case, the span of observation was shortened to six years since information on congenital malformations for 1978 was not available from the California Department of Health Services. As indicated in Table VII-11, the slopes for each of the four areas and the combined areas were negative, indicating a slight downward trend in occurrence of malformations based on the Los Angeles County experience. In addition, the slopes were not significantly different from one

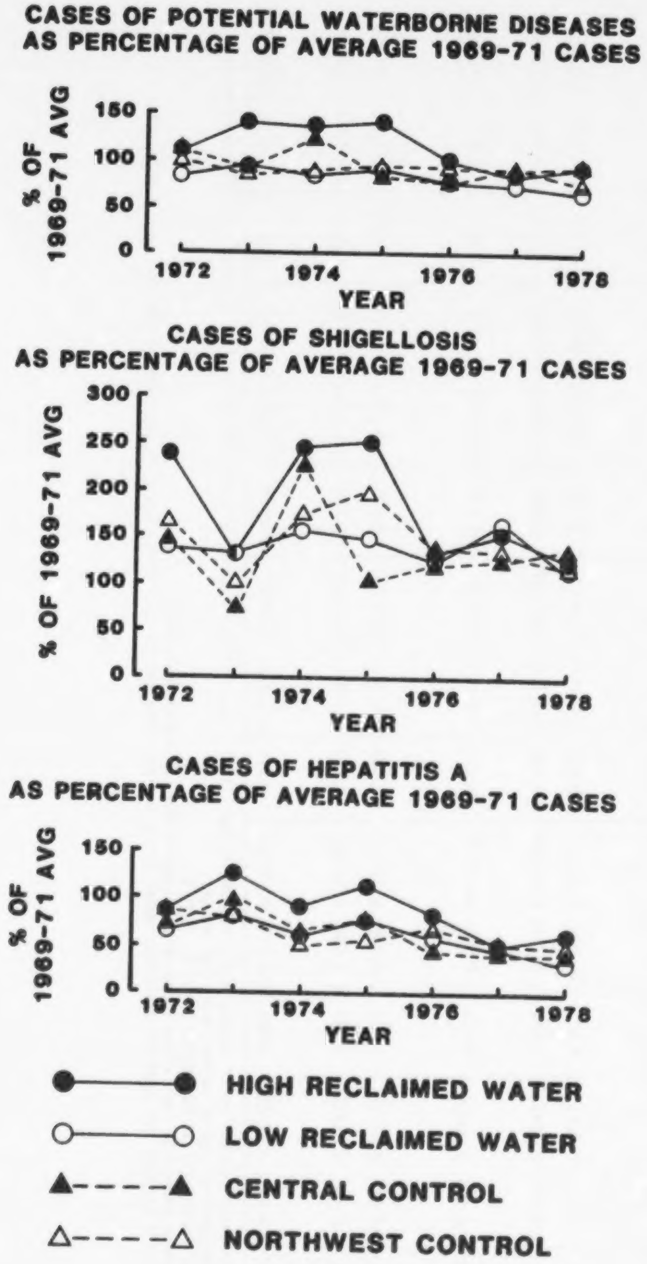


FIGURE VII-6

MORBIDITY PATTERNS 1972-78

TABLE VII-11

COMPARISONS OF SECULAR TRENDS OF BIRTH OUTCOMES OR DEATH DURING THE FIRST YEAR OF LIFE AMONG RECLAIMED WATER AREAS AND CONTROL AREAS, 1972-78

	Low Weight Births		Very Low Weight Births		Congenital Malformations		Infant Mortality		Neonatal Mortality	
Geographic Area	Slope[a]	95% Confidence Interval[b]	Slope[a]	95% Confidence Interval[b]	Slope[a]	95% Confidence Interval[b]	Slope[a]	95% Confidence Interval[b]	Slope[a]	95% Confidence Interval[b]
Reclaimed water area										
Low (<5%)	0.002	(-0.016, 0.020)[c]	0.001	(-0.033, 0.035)[c]	-0.021	(-0.058, 0.016)[c]	-0.022	(-0.048, 0.005)[c]	-0.002	(-0.028, 0.025)[c]
High (≥5%)	-0.024	(-0.053, 0.004)[c]	0.021	(-0.031, 0.073)[c]	-0.028	(-0.090, 0.035)[c]	-0.020	(-0.066, 0.026)[c]	-0.011	(-0.062, 0.040)[c]
Combined water areas	-0.008	(-0.024, 0.008)[d]	0.005	(-0.023, 0.034)[d]	-0.022	(-0.054, 0.009)[d]	-0.022	(-0.045, 0.001)[d]	-0.004	(-0.028, 0.019)[d]
Control areas										
Northwest	0.001	(-0.015, 0.017)[c]	-0.013	(-0.040, 0.013)[c]	-0.018	(-0.063, 0.028)[c]	-0.024	(-0.047,-0.001)[c]	-0.049	(-0.073, -0.024)[c]
Central	0.023	(-0.008, 0.054)[c]	0.042	(-0.006, 0.091)[c]	-0.007	(-0.077, 0.062)[c]	-0.036	(-0.082, 0.011)[c]	-0.023	(-0.075, 0.028)[c]
Combined control areas	0.006	(-0.009, 0.020)[d]	0.003	(-0.020, 0.026)[d]	-0.014	(-0.052, 0.024)[d]	-0.027	(-0.048,-0.006)[d]	-0.042	(-0.064, -0.020)[d]

[a] Derived from weighted linear regression of standardized ratios on year (1972 = 1,..,1978 = 7), adjusted for age of mother; congenital malformations and mortality outcomes adjusted for age of mother and birth weight.

[b] Interval around slope = SLOPE ± 1.96 [STANDARD ERROR OF SLOPE].

[c] No significant difference among the four areas based on overlapping 95% confidence intervals.

[d] No significant difference between the combined reclaimed water areas and the combined control areas based on overlapping 95% confidence intervals.

TABLE VII-12

COMPARISON OF BIRTH OUTCOMES OR DEATHS DURING THE FIRST YEAR OF LIFE AMONG RECLAIMED WATER AREAS AND CONTROL AREAS, 1972-78

	Control Areas				Reclaimed Water Areas					Combined Areas				
	Northwest		Central		Low (<5%)		High (≥5%)		Significance[b]/	Control		Reclaimed		Significance[c]/
Birth Related Health Outcomes	Number of Events	SR[a]/	Number of Events	SR[a]/	Number of Events	SR[a]/	Number of Events	SR[a]/	P	Number of Events	SR[a]/	Number of Events	SR[a]/	P
Birth Outcomes														
Low weight births	2,662	0.76	791	0.74	2,633	0.81	664	0.72	< 0.001	3,453	0.76	3,297	0.79	NS
Very low weight births	368	0.74	108	0.71	402	0.87	98	0.75	0.04	476	0.73	500	0.84	NS
Congenital malformations	428	1.06	97	0.79	264	0.71	69	0.66	0.002	525	1.00	333	0.70	0.004
Death Outcomes														
Infant deaths	525	0.76	168	0.81	624	0.91	143	0.79	< 0.001	693	0.77	767	0.88	<0.001
Neonatal deaths	351	0.72	112	0.77	413	0.84	96	0.76	< 0.001	463	0.73	509	0.82	0.002

a/ Average standardized ratios; observed events in 1972-78 divided by expected events in 1972-78 based on 1969-71 Los Angeles County age of mother- and birth weight-specific rate of birth outcomes or death outcomes (SR for Los Angeles County = 1.0).

b/ Level of significant difference among the four areas, analysis of covariance; NS = not significant ($P \geq 0.05$).

c/ Level of significant difference between combined reclaimed water areas and combined control areas, analysis of covariance; NS = not significant ($P \geq 0.05$).

another based on the overlapping 95 percent confidence intervals. However, there were statistically significant differences among the four areas and the combined areas in the size of the standardized ratios as shown in Table VII-12. In the case of the four areas, the difference was attributed to the SR of the northwest control area which was just slightly greater than expected, but significantly higher than the exposed areas. In the case of the combined areas, the SR of the exposed areas was significantly less than the control areas. These results were not affected by adjusting for the potential confounding effects of race, in addition to age of mother and birth weight.

Patterns of Infant Mortality, 1972-78

Standardized ratios, adjusted for the potential confounding effects of maternal age and infant birth weight were derived for infant deaths (less than one year) and neonatal deaths (less than 28 days) for the four study areas and the combined control and exposed areas. The standard for the SRs was the infant or neonatal mortality rate for Los Angeles County in 1969-71. Figures depicting the standardized mortality ratios over time have been included in Appendix O. Due to continuing medical progress, it was anticipated that these rates would decline over time. The results of the weighted linear regression analyses indicated that the estimated linear slopes were all negative, a finding in accordance with this theory (see Table VII-11). Furthermore, the slopes of the four study areas and the slopes of the combined exposed and combined control areas were not significantly different based on the overlapping 95 percent confidence intervals.

Results of the covariance analyses for infant mortality patterns which are presented in Table VII-12 indicated that all of the areas had lower standardized mortality ratios than occurred in Los Angeles County during 1969-71. There was a significant difference among the four study areas ($P \leq 0.05$) with the low reclaimed water area having the highest SRs. This finding, however, did not support the water contaminant hypothesis. The combined exposure areas had significantly greater SRs than the combined control areas; the difference was attributed to the higher ratios for the low reclaimed water area.

HEALTH AND VITAL STATISTICS DATA 1979-80

For the analysis of the 1979-80 data, the 1960-70 correspondence tracts used in the previous analyses were replaced by the 1980 census tracts as the units of analysis, since both the numerator and denominator data were coded with 1980 census tracts. The geographic areas contained within each of the four study areas (low reclaimed water, high reclaimed water, northwest control, and central control) were the same as in the 1972-78 analysis (see Figure VII-3). There were 200 census tracts (1980 U.S. Census) in the four areas combined: 64 in the low reclaimed water area, 23 in the high reclaimed water area, 87 in the northwest control area, and 26 in the central control area. According to U. S. Census figures (Table VII-13) in April 1980, 362,697 persons resided in the low reclaimed water area, 123,376 persons in the high reclaimed water area, 450,777 in the northwest control area, and 124,850 in the central control area. Additional characteristics of the populations in these four areas are shown in Table VII-13. In general, the areas were similar in terms of age distribution,

TABLE VII-13

GENERAL POPULATION CHARACTERISTICS FOR TWO RECLAIMED WATER AREAS AND TWO CONTROL AREAS USED FOR THE 1979-80 ANALYSES, 1980 CENSUS

Variable	Control Areas		Reclaimed Water Areas	
	Northwest	Central	Low(<5%)	High(>5%)
General population data				
Total population	450,777	124,850	362,697	123,276
Number of males	215,375	61,452	176,387	59,981
Number of females	235,402	63,398	186,310	63,295
Persons under 18 per 100 persons 18-64 years	46.3	52.3	52.1	50.4
Persons 65 and over per 100 persons 18-64	19.3	13.7	15.5	13.1
Ethnic composition				
White (%)	69.0	74.6	77.1	76.3
Spanish Origin (%)	42.9	52.4	49.2	56.5
Black (%)	1.0	0.6	0.9	0.3
Other (%)	30.0	24.8	22.0	23.4
Socioeconomic status				
Percent of occupied housing units that are renter-occupied	49.8	40.4	51.0	29.7
Percent of occupied housing units with 1.01 or more persons per room	12.5	15.1	15.7	12.3

racial/ethnic composition, and housing characteristics. About half the population in each area was of Spanish origin or descent, while less than one percent was black.

A list of health outcomes evaluated for the 1979-80 analyses is shown in Table VII-14. Each disease or group of diseases was classified according to the International Classification of Diseases (ICD) code, Ninth Revision (VII-24). The ICD number appeared on records in the machine-readable files provided by the Los Angeles County Department of Health Services and the Los Angeles County/University of Southern California (LAC/USC) Comprehensive Cancer Center. No ICD codes were used for the birth-related outcomes. In addition, incident cancer data for malignant neoplasms of the stomach, colon, rectum and bladder were evaluated. These data were obtained from the LAC/USC Comprehensive Cancer Center.

Statistical Analysis

Two methods of adjustment were used for the confounding variables in the 1979-80 analyses: the indirect and direct methods. The indirect method of adjustment consisted of applying subgroup-specific rates based on the experience of the standard population to the number of persons at risk in the corresponding subgroup in the study population yielding an expected number of events (E). The expected number of events was compared to an observed number of events in the form of a ratio (O/E). The standard population in this case was Los Angeles County during 1979-80. The procedure for deriving a standardized ratio is represented by the following equation:

$$SR = \frac{e}{\sum_{i=1}^{k} n_i \left(\frac{E_i}{N_i}\right)} = \frac{\text{Observed}}{\text{Expected}}$$

where e = observed number of events in the study population,
E_i = number of events in the ith subgroup of the standard population,
n_i = number of persons at risk (or number of births) in the ith subgroup of the study population,
and k = the number of subgroups used in the analysis.

Standardized ratios were calculated for all 1979-80 data, including deaths due to all causes, deaths due to a specific cause (standardized mortality ratio), diagnosed cases of cancer (standardized cancer incidence ratio), infant deaths (standardized infant mortality ratio), neonatal deaths (standardized neonatal mortality ratio), low weight births (standardized low birth weight ratio), very low weight births (standardized very low birth weight ratio), and cases of reportable disease (standardized morbidity ratio). Each of these indexes is described in more detail below.

TABLE VII-14

INTERNATIONAL CLASSIFICATION OF DISEASES (ICD), NINTH REVISION (1978), CLINICAL MODIFICATION

Diseases of the heart	390-398,402,404-429
Cerebrovascular diseases (stroke)	430-438
Malignant neoplasms (cancer)	140-208
Stomach	151
Colon	153
Rectum	154.1
Bladder	188
Potential waterborne diseases	
Typhoid fever	002.0
Salmonellosis	003
Shigellosis	004
Amebiasis	006
Meningococcal infections	036
Meningitis of etiology other than mumps	047
Meningitis of undetermined etiology	047
Hepatitis A	070.0-070.1
Leptospirosis	100

Standardized Mortality Ratios (SMRs). Standardized mortality ratios were calculated for deaths due to all causes, for death due to diseases of the heart, cerebrovascular disease, all malignant neoplasms, and for deaths due to malignant neoplasms at four sites (stomach, colon, rectum, and bladder). Age-, sex-, and cause-specific death rates for Los Angeles County residents during the years 1979 and 1980 were applied to the corresponding age and sex subgroups of the population in each census tract to calculate the expected number of deaths for each cause. Ten 10-year age groups (0-4, 5-14, ..., 85+) were used in the adjustment procedure. The standard rates used to calculate the expected number of deaths were derived from the death certificate files prepared from the State of California vital statistics records and population data from the 1980 U.S. Census (VII-25). The SMRs for each census tract were formed by dividing the observed number of deaths by the corresponding expected number of deaths calculated for the census tract.

Standardized Incidence Ratios (SIRs). Standardized incidence ratios were calculated for newly diagnosed cases of four malignant neoplasms: stomach, colon, rectum, and bladder. Age-, sex-, and site-specific incidence rates for Los Angeles County during the years 1979 and 1980 were applied to corresponding age and sex subgroups of the population in each area to calculate the expected number of cases for each site. Ten 10-year age groups (0-4, 5-14, ..., 85+) were used in the adjustment procedure. The standard rates used to calculate the expected number of cases were derived from data prepared by the Los Angeles County/University of Southern California Cancer Center and population data from the 1980 U.S. Census (VII-25). The SIRs were formed by dividing the observed number of cases by the corresponding expected number of cases calculated for the study area.

Standardized Infant Mortality Ratios (SIMRs). Standardized infant mortality ratios were calculated for infant deaths (under one year of age) while standardized neonatal mortality ratios (SNMRs) were calculated for neonatal deaths (under 28 days of age). The standardization procedure was used to adjust for maternal age and birth weight, two factors that have been associated with infant and neonatal mortality. Infant deaths were grouped by four 1000-gram birth weight categories ($\leq$1500, 1501-2500, 2501-3500, 3501+) and four 10-year age-of-mother categories (less than 20, 20-29, 30-39, 40+) for use in the adjustment procedure. Maternal age- and birth weight-specific infant and neonatal death rates for Los Angeles County residents during the years 1979 and 1980 were applied to the corresponding maternal age and birth weight subgroups of 1979-80 live births in each census tract to calculate the expected number of infant and neonatal deaths. The standard rates used to calculate the expected number of infant deaths and neonatal deaths were derived from the linked birth-infant death files and the birth files prepared from the State of California and County of Los Angeles vital statistics records. The SIMRs and SNMRs for each census tract were formed by dividing the observed number of deaths among infants born in 1979-80 by the expected number of deaths calculated for the census tract.

The data also were analyzed with race/ethnicity included in the adjustment procedure. In the adjustment for race/ethnicity, the population was categorized into four mutually exclusive categories: white, non-Spanish-surname; white, Spanish-surname; black; and other races.

Standardized Low Birth Weight Ratios (SLBWRs). Standardized low birth weight ratios were calculated for births weighing less than or equal to 2,500 grams (low birth weight), and standardized very low birth weight ratios (SVLBWRs) for births weighing less than or equal to 1,500 grams (very low birth weight). The standardization procedure was used to adjust for maternal age, a factor that has been associated with low weight births. Births were grouped by eight 5-year maternal age categories (less than 15, 15-19, ..., 45+). Maternal age-specific rates of low birth weight for Los Angeles County residents during the years 1979 and 1980 were applied to the corresponding maternal age subgroups of 1979-80 live births in each census tract in order to calculate the expected number of low birth weight infants. The standard rates used to calculate the expected number of low weight births were derived from the birth files prepared from the State of California vital statistics records. The SLBWRs for each census tract were formed by dividing the observed number of low weight births by the corresponding expected number of low weight births calculated for the census tract. The data also were analyzed with four categories of race/ethnicity included in the adjustment procedure. The same procedure was followed for deriving SVLBWRs, except that the analysis included only very low weight births.

Standardized Morbidity Ratios (SMRs). Standardized morbidity ratios were calculated for all potential waterborne disease combined, hepatitis A, and shigellosis. Diseases in the category "all potential waterborne disease" include hepatitis A, shigellosis, meningitis of undetermined etiology, amebiasis, leptospirosis, meningitis of etiology other than mumps, meningococcal infections, Salmonella infections, and typhoid. Age- and sex-specific disease rates for Los Angeles County residents during the years 1979 and 1980 were applied to the corresponding age and sex subgroups of the population in each census tract to calculate the expected number of cases for each disease. Ten 10-year age groups (0-4, 5-14, ..., 85+) were used in the adjustment procedure. The standard rates used to calculate the expected number were derived from the confidential morbidity records complied by the Los Angeles County Department of Health Services (VII-26) and population data from the 1980 U.S. Census (VII-25). The SMRs for each census tract were formed by dividing the observed number of cases of disease by the corresponding expected number of cases calculated for the census tract.

Testing for Differences Among the Four Areas. Using the 200 census tracts making up the overall study area, standardized ratios were calculated for each of the four study areas according to the following equation:

$$\text{Standardized ratio} = \frac{\sum_{i=1}^{k} O_i}{\sum_{i=1}^{k} E_i}$$

where O_i = number of observed events in census tract_i,
E_i = number of expected events in census tract_i,
and k = number of census tracts in each area.

A ratio greater than 1.0 indicated that more events occurred than were expected, given the Los Angeles County rates, while a ratio less than 1.0 indicated that fewer events occurred than were expected, given Los Angeles County rates.

An assumption was made, for each census tract, that the observed number of events followed a Poison distribution with a mean equal to the expected number of events. The normal approximation to the Poison allowed the calculation of a standardized normal deviate for each census tract (VII-15). A one-way analysis of variance was used to test for differences among the four study areas for all 1979-80 outcomes, except incident cases of malignant neoplasm for which the necessary data were not available.

Direct Adjustment. In addition to the standardized ratios discussed above, the vital statistics data for 1979-80 were adjusted using the direct method. In the direct adjustment technique, the specific rates in the four-study populations were applied to the standard population, namely the population of Los Angeles County during 1980 (or live births in Los Angeles County during 1979-80). Thus, for each outcome examined, rates for the four study areas were calculated based on the same subgroups (e.g., age, sex, race, birth weight) that were used when calculating the standardized ratio described above. Then, for each study area, the subgroup-specific rates were multiplied by the appropriate subgroup in the standard population; that is, residents of Los Angeles County in 1980 or County births during 1979-80. This yielded the expected number of deaths, births, or cases of disease that would occur in the County, assuming they had experienced the rates in the study areas. The expected number was divided by the total number of people at risk (or the total number of live births) in the standard population to yield the adjusted rate relative to the subgroup rates of the study area.

The method for calculating a directly adjusted rate (DAR) is described by the following equation:

$$\text{DAR} = \frac{\sum_{i=1}^{k} \left(\frac{e_i}{n_i}\right) N_i}{N}$$

where e_i = number of events in the ith subgroup of the study population,
n_i = number of persons at risk (or number of births) in the ith subgroup of the study population,
N_i = number of persons at risk (or number of births) in the ith subgroup of the standard population,
N = total number of persons at risk (or number of births) in the standard population,
and k = the number of subgroups used in the analysis.

Directly adjusted rates were calculated for all 1979-80 outcomes, including mortality due to all causes and to eight specific causes, incident cases of four malignant neoplasms, infant mortality, neonatal mortality, low weight births, very low weight births, and cases of reportable disease.

The Mantel-Haenszel chi-square statistic (VII-27) was used to test for differences among the directly adjusted rates in the four study areas. For each subgroup in the analysis, the subgroup-specific rates for each of the four study areas were compared to a rate for the four areas combined. The chi-square statistic was used to determine if there was an overall difference among the four areas. For an analysis where the relationship among rates is the same in each subgroup, this statistical test is considered to be the most powerful method for detecting an association between an exposure and outcome (VII-28).

The method consists of computing a chi-square statistic with 3 degrees of freedom based on a multinomial distribution. Using this method, the assumption is made that there are a fixed number of events in the four areas combined within each subgroup and that there is independence in the morbidity and mortality experience among the four areas.

The chi-square procedure described above has also been extended to test for an ordinal relationship between three or more exposure categories (VII-29). This adaptation allows testing of a linear dose-response relationship between exposure and outcome. For the 1979-80 analyses, the values of 1 and 2 were assigned to the low reclaimed water area and high reclaimed water area, respectively, to reflect the level of exposure to reclaimed water. The two control areas (northwest and central) were each assigned the value of 0. This procedure has the greatest power for detecting an effect of exposure, under the assumption that the high reclaimed water area experienced a two-fold increase in risk over the low reclaimed water area. Although other patterns of increasing disease rates with exposure could be detected, the procedure is most sensitive for detecting the relationship specified by the assigned values.

The chi-square statistic tests for a linear increase in the rates according to the assigned values of 0, 1, and 2. The statistic was compared to a chi-square table with one degree of freedom to determine whether or not a statistically significant linear trend existed among the four areas.

Patterns of Mortality, 1979-80

The findings for the various causes of death investigated are shown in Table VII-15. Figures depicting mortality rates for five age groups have been included in Appendix O.

For deaths due to all causes, the standardized mortality ratios and directly adjusted rates for each of the four study areas were less than the Los Angeles County SMR and DAR of 1.0 and 802.92, respectively. However, the four areas were significantly different in their mortality experience because of the higher SMR and DAR for the low reclaimed water area and the lower SMR and DAR for the central control area as shown in Table VII-15. When considering individually the major causes of death potentially associated with exposure to waterborne contaminants (see Table VII-15), there were no significant differences between the areas in deaths due to heart disease or cerebrovascular disease. In addition, the mortality rates were lower than those in Los Angeles County.

When considering another broad category of death, all malignant neoplasms, there were differences among the four study areas as shown in Table VII-15. All

TABLE VII-15

COMPARISON OF DEATHS AMONG TWO RECLAIMED WATER AREAS AND TWO CONTROL AREAS, ADJUSTED FOR AGE AND SEX, 1979-80

Mortality Category	Control Areas						Reclaimed Water Areas						Significance	
	Northwest			Central			Low (< 5%)			High (≥ 5%)			P	
	Number of Events	SPIR a/	DAR b/	Number of Events	SMR a/	DAR b/	Number of Events	SMR a/	DAR b/	Number of Events	SMR a/	DAR b/	SMR c/	DAR d/
All causes	7,358	0.91	724.36	1,519	0.85	689.36	5,321	0.97	782.52	1,548	0.90	737.98	0.003	<0.001
Diseases of heart	3,070	0.96	293.03	603	0.91	283.74	2,016	0.98	302.51	603	0.96	310.26	NS	NS
Cerebrovascular diseases	680	0.85	62.79	119	0.77	57.20	443	0.91	67.15	104	0.75	55.33	NS	NS
Malignant neoplasms	1,492	0.90	151.56	310	0.82	137.91	1,138	0.98	164.95	341	0.88	149.72	0.04	0.02
of the stomach	59	0.87	6.05	18	1.19	8.14	42	0.90	6.13	18	1.18	8.57	NS	NS
of the colon	165	0.95	16.33	26	0.69	12.14	109	0.93	15.92	22	0.59	9.48	NS	NS
of the rectum	35	1.14	3.44	3	0.45	1.33	13	0.63	1.94	10	1.52	4.94	NS	NS
of the bladder	39	0.99	3.92	9	1.09	4.24	26	1.01	3.88	10	1.24	4.76	NS	NS
All other causes	2,116	0.86	216.99	487	0.82	210.51	1,724	0.97	247.90	500	0.88	222.67	0.01	<0.001

a/ Standardized mortality ratio; observed events in 1979-80 divided by expected events in 1979-80 based on Los Angeles County age- and sex-specific mortality rates (SMR for Los Angeles County = 1.0).

b/ Directly adjusted mortality rates per 100,000 persons per year using 1980 Los Angeles County population as standard (average annual mortality rates for Los Angeles County 1979-80: 802.92 deaths due to all causes per 100,000 population; 307.25 deaths due to diseases of the heart per 100,000 population; 73.85 deaths due to cerebrovascular disease per 100,000 population; 167.75 deaths due to cerebrovascular disease per 100,000 population; 167.75 deaths due to malignant neoplasms per 100,000 population; 6.83 deaths due to malignant neoplasm of the stomach per 100,000 population; 17.14 deaths due to malignant neoplasm of the colon per 100,000 population; 3.04 deaths due to malignant neoplasm of the rectum per 100,000 population; 3.83 deaths due to malignant neoplasm of the bladder per 100,000 population; 254.07 deaths due to all other causes per 100,000 population).

c/ Level of significant difference among the SMRs of the four areas, one way analysis of variance; NS = not significant (P ≥ 0.05).

d/ Level of significant difference among the DARs of the four areas, Mantel-Haenszel nominal test of association; NS = not significant (P ≥ 0.05).

four areas had SMRs or DARs that were lower than those for Los Angeles County. The four areas were significantly different based on statistical evaluation. However, the pattern of differences (i.e., low reclaimed water area having a higher rate than the high reclaimed water area) was not in accord with the biological hypothesis that increased concentration of reclaimed water contributed to an increased rate of disease. For deaths due to malignant neoplasm of the stomach, colon, rectum and bladder, the SMRs and DARs shown in Table VII-15 indicate that there were differences among four areas; however, in each case the differences were not statistically significant.

Finally, for all deaths not due to diseases of the heart, cerebrovascular disease or malignant neoplasms which were categorized as "deaths due to all other causes", there were differences among the four study areas. As shown in Table VII-15, the rates in the low reclaimed water area were higher than the rates in the high reclaimed water area. The differences were statistically significant for both tests employed in the analysis. All four areas had ratios or rates, however, that were less than those of Los Angeles County.

For the various causes of death, an additional analysis was conducted to determine whether or not there was an increasing linear trend in the data; this trend would support the hypothesis that residence in an area receiving reclaimed water contributed to an increase in mortality. If the hypothesis was true, the reclaimed water areas would have to have higher death rates than the control areas and the high reclaimed water area would exhibit a higher death rate than the low reclaimed water area. A value of two was assigned to the high reclaimed water area, one to the low reclaimed water area and zero to each of the control areas, to determine if there was a linear trend which supported the tested hypothesis. If reclaimed water had contributed to mortality, then an increasing linear trend would have appeared in the analysis. The findings from the linear trend analysis of the nine death categories are shown in Table VII-16. For only two of the causes of death were the linear trends statistically significant: death due to all causes and the final category, death due to all other causes. In both these instances, there was an increasing trend in accordance with the hypothesis that reclaimed water contributed to excess mortality; however, the mortality rates in the low reclaimed water area for the two death categories were greater than those in the high reclaimed water area, a finding that significantly detracted from the credibility of the stated hypothesis.

Incidence of Cancer, 1979-80

For the years 1979-80, standardized ratios and adjusted rates were derived for the incidence of four types of cancer. Rather than deaths per population at risk, the analysis focussed on newly diagnosed cases of stomach, colon, rectal and bladder cancer per population at risk. If any of the cases died in either 1979 or 1980, they would be included in the analysis of cancer mortality previously described. Those who survived would not be included in the analysis of mortality, but would be included with the incidence results. These are cancer cases who survived through the end of 1980 or who moved out of the study area prior to death. Figures showing incidence rates by age group have been included in Appendix O.

TABLE VII-16

ANALYSIS OF LINEAR TREND AMONG COMBINED CONTROL AREAS AND TWO RECLAIMED WATER AREAS, SELECTED CAUSES OF DEATH, 1979-80

Cause of Death	Adjusted Rate per 100,000 Population per Year a/			Linear Trend c/	Significance P d/
	Combined Control Areas b/ (0)	Reclaimed Water Areas			
		Low (1)	High (2)		
All causes	717.87	782.52	737.98	Increasing	0.007
Diseases of the heart	291.43	302.51	310.26	Increasing	0.24
Cerebrovascular disease	61.85	67.15	55.33	Decreasing	0.96
Malignant neoplasms	148.87	164.95	149.72	Increasing	0.24
Stomach	6.29	6.13	8.57	Increasing	0.61
Colon	15.54	15.92	9.48	Decreasing	0.17
Rectum	3.10	1.94	4.94	Increasing	0.82
Bladder	3.96	3.88	4.76	Increasing	0.70
All other causes	215.73	247.90	222.67	Increasing	0.01

a/ Adjusted for age and sex using direct method, 1979-80 Los Angeles County population as standard.

b/ Weighted average of two control rates using inverse of variance as weight.

c/ Estimate of linear trend based on scoring of exposure to reclaimed water in study areas: northwest control area = 0, central control area = 0, low reclaimed water area = 1, and high reclaimed water area = 2.

d/ Level of statistical significance based on Mantel chi-square test for linear trend.

Summary statistics for stomach cancer incidence, adjusted for population differences in age and sex, are shown in Table VII-17. The standardized incidence ratios and the directly adjusted incidence rates are similar to those observed for Los Angeles County. For the incidence data, analyses were limited to the more sensitive of the two statistical tests presented earlier, the Mantel-Haenszel nominal test of association. Among the four study areas, there were no significant differences observed in the directly adjusted incidence rates for stomach cancer. For malignant neoplasm of the colon, the SIRs and DARs for the high reclaimed water area were nearly identical to those of the central control area, while the ratios and rates for the low reclaimed water area were similar to those for the northwest control area. Among the reclaimed water areas, the low area had a higher rate of colon cancer than the high area which, in turn, had a much lower rate than the rate for Los Angeles County. The differences among the four areas were statistically significant (p=0.002), although the pattern of those differences was not in accord with the biological hypothesis that reclaimed water contributed to an increase in colon cancer.

For malignant neoplasm of the rectum, both of the reclaimed water areas had lower SIRs and adjusted incidence rates than those of either of the two control areas, or of the total County (see Table VII-17). The differences between the four areas, however, were not statistically significant. For the last of the four types of cancer being considered in this investigation, there was no significant difference among the four study areas in the adjusted incidence rates for bladder cancer. In general, the rates in all four areas tended to be either lower than or equal to those of Los Angeles County.

If the consumption of reclaimed water had caused one of the four types of cancer, both of the reclaimed water areas would have exhibited rates greater than the control areas and the high reclaimed water area would have had a rate greater than the low reclaimed water area. As seen in Table VII-18, this hypothesized trend was not observed for any of the four types of malignant neoplasms. Instead of an increasing trend with increased concentration of reclaimed water, the data showed a decreasing trend in each of the cancer types with increased concentration of reclaimed water. For three of the four types of cancer, the linear trend was not statistically significant, while for rectal cancer the observed decreasing trend was significant. This decreasing trend, however, was in the opposite direction of what would be expected if the biological hypothesis that reclaimed water caused rectal cancer were true.

Patterns of Potential Waterborne Diseases, 1979-80

Nine infectious diseases which have been incriminated in other studies of waterborne contaminants were included in the 1979-80 analysis: typhoid fever, salmonellosis, shigellosis, amebiasis, meningococcal infections, meningitis of etiology other than mumps, meningitis of undetermined etiology, hepatitis A, and leptospirosis. Figures depicting the incidence rates for all of the potential waterborne diseases by age of the patient and study area have been included in Appendix O. A comparison of the standardized morbidity ratios (observed cases divided by expected cases based on the experience in Los Angeles County) and the adjusted waterborne disease rates, by study area in Table VII-19, showed that there were some overall differences among the four study areas. A curious

TABLE VII-17

COMPARISON OF CANCER INCIDENCE AMONG RECLAIMED WATER AREAS AND CONTROL AREAS, ADJUSTED FOR AGE AND SEX, 1979-80

Cancer Incidence Category	Control Areas						Reclaimed Water Areas						Significance P DAR c/
	Northwest			Central			Low (< 5%)			High (≥ 5%)			
	Number of Events	SIR a/	DAR b/	Number of Events	SIR a/	DAR b/	Number of Events	SIR a/	DAR b/	Number of Events	SIR a/	DAR b/	
Malignant neoplasm of the stomach	99	1.04	10.12	23	1.06	10.36	58	0.87	8.45	25	1.14	12.11	NS
Malignant neoplasm of the colon	282	0.94	28.01	40	0.61	18.55	202	1.00	29.40	40	0.62	18.08	0.002
Malignant neoplasm of the rectum	99	1.16	10.03	21	1.08	9.29	49	0.82	7.13	12	0.60	6.09	NS
Malignant neoplasm of the bladder	136	1.04	13.72	23	0.78	10.47	88	0.96	12.69	26	0.85	11.64	NS

a/ Standardized incidence ratio; observed cases in 1979-80 divided by expected cases in 1979-80 based on Los Angeles County age- and sex-specific incidence rates (SIR for Los Angeles County = 1.0).

b/ Directly adjusted incidence rate per 100,000 persons per year using 1980 Los Angeles County population as standard (average annual incidence rates for Los Angeles County, 1979-80: 9.72 cases of malignant neoplasm of the stomach per 100,000 population, 29.68 cases of malignant neoplasm of the colon per 100,000 population, 8.69 cases of malignant neoplasm of the rectum per 100,000 population, 13.35 cases of malignant neoplasm of the bladder per 100,000 population).

c/ Level of significant difference among the DARs of the four areas, Mantel-Haenszel nominal test of association; NS = not significant ($P \geq 0.05$).

TABLE VII-18

ANALYSIS OF LINEAR TREND AMONG COMBINED CONTROL AREAS AND TWO RECLAIMED WATER AREAS, INCIDENT CASES OF MALIGNANT NEOPLASM, 1979-80

Site of Malignant Neoplasm	Adjusted Rate per 100,000 Population per Year a/			Linear Trend c/	Significance p d/
	Control Areas b/ (0)	Reclaimed Water Areas			
		Low (1)	High (2)		
Stomach	10.15	8.45	12.11	Decreasing	0.77
Colon	25.95	29.40	18.08	Decreasing	0.31
Rectum	9.91	7.13	6.09	Decreasing	0.01
Bladder	13.12	12.69	11.64	Decreasing	0.51

a/ Adjusted for age and sex using direct method, 1979-80 Los Angeles County population as standard.

b/ Weighted average of two control rates using inverse of variance as weight.

c/ Estimate of linear trend based on scoring of exposure to reclaimed water in study areas: northwest control area = 0, central control area = 0, low reclaimed water area = 1, and high reclaimed water area = 2.

d/ Level of statistical significance based on Mantel chi-square test for linear trend.

TABLE VII-19

COMPARISON OF ILLNESSES AMONG TWO RECLAIMED WATER AREAS AND TWO CONTROL AREAS, ADJUSTED FOR AGE AND SEX, 1979-80

Disease Category	Control Areas						Reclaimed Water Areas						Significance	
	Northwest			Central			Low (< 5%)			High (≥ 5%)			P	
	Number of Cases	SMR a/	DAR b/	Number of Cases	SMR a/	DAR b/	Number of Cases	SMR a/	DAR b/	Number of Cases	SMR a/	DAR b/	SMR c/	DAR d/
All potential waterborne diseases	634	1.03	68.74	239	1.35	89.67	537	1.03	68.81	144	0.86	57.57	NS	<0.001
Hepatitis A	166	1.03	18.49	47	1.04	18.75	142	1.09	19.57	48	1.10	19.41	NS	NS
Shigellosis	181	0.87	19.36	102	1.69	37.24	209	1.16	25.41	39	0.68	15.58	NS	<0.001

a/ Standardized morbidity ratio; observed number of cases in 1979-80 divided by expected cases in 1979-80 based on Los Angeles County age- and sex-specific morbidty rates (SMR for Los Angeles County = 1.0).

b/ Directly adjusted morbidity rates per 100,000 persons per year using 1980 Los Angeles County population as standard (average annual waterborne morbidity rate for Los Angeles County, 1979-80: 67.07 cases of reported potential waterborne diseases per 100,000 population; 18.22 cases of reported hepatitis A per 100,000 population; 22.21 cases of reported shigellosis per 100,000 population).

c/ Level of significant difference among the SMRs of the four areas, one way analysis of variance; NS = not significant ($P \geq 0.05$).

d/ Level of significant difference among the DARs of the four areas, Mantel-Haenszel nominal test of association; NS = not significant ($P \geq 0.05$).

finding emerged when the results of the two statistical tests were compared. In prior analyses, the two tests were reasonably close in the level of statistical significance. However, in Table VII-19, the analysis of variance for the standardized morbidity ratios indicated the difference between the four groups was not significant, while the Mantel-Haenszel nominal test of association for directly adjusted rates indicated the difference between the four groups was statistically significant. As mentioned earlier, the Mantel-Haenszel nominal test is considered to be a more sensitive test and should be relied on when discrepancies exist between the analyses. It is likely that the method used to test for differences among the standardized ratios was especially susceptible to a bias with diseases that cluster in small geographic areas. This problem potentially exists with many of the infectious diseases included in the present analysis. Focusing again on Table VII-19, the rates in the two reclaimed water areas were similar to those both in the northwest control area and in Los Angeles County, and considerably lower than those in the central control area. The lowest rate among the four study areas was in the high reclaimed water area.

While a detailed analysis of each of the nine potential waterborne diseases was not feasible due to the small number of cases in the study areas, the occurrence of two diseases, hepatitis A and shigellosis was further evaluated. As shown in Table VII-19, the SMRs and DARs were slightly greater in the reclaimed water areas; however, the differences were not found to be statistically significant by either statistical test. For shigellosis, there were considerable differences among the results in the four study areas (see Table VII-19). The lowest SMR and adjusted rate occurred in the high reclaimed water area, while the highest levels occurred in the central control area. Based on the more sensitive Mantel-Haenszel nominal test of association, the differences among the four areas were statistically significant.

A further evaluation was conducted to determine if the data followed an increasing linear trend with respect to exposure to reclaimed water. In the linear trend analysis, the high reclaimed water area was assigned a value of two, the low reclaimed water area, a value of one, and two control areas, values of zero. As shown in Table VII-20, an increasing trend existed only for hepatitis A, and the trend was not statistically significant.

Patterns of Birth-Related Health Outcomes, 1979-80

The 1979-80 analysis of birth-related data evaluated four health outcomes: low weight birth, very low weight birth, infant mortality, and neonatal mortality. For the low and very low weight birth categories, the age of mother at the time of birth and the race of the child were controlled in the analyses. Figures depicting weight at birth according to the distribution of maternal age have been included in Appendix O. As shown in Table VII-21, the proportions of low weight births and very low weight births in the four study areas were less than those in Los Angeles County. There were also no statistically significant differences among the SLBWRs, SVLBWRs, or DARs for the four areas when controlling for age of mother. Similar findings were noted when controlling for both maternal age and race of child.

An additional analysis was conducted to determine whether residence in the reclaimed water area was associated with an increased linear trend in low or

TABLE VII-20

ANALYSIS OF LINEAR TREND AMONG COMBINED CONTROL AREAS AND TWO RECLAIMED WATER AREAS, SELECTED REPORTABLE DISEASES, 1979-80

Disease	Adjusted Rate per 100,000 Population per Year a/			Linear Trend c/	Significance P d/
	Control Areas b/ (0)	Reclaimed Water Areas			
		Low (1)	High (2)		
All potential waterborne diseases	72.39	68.81	57.57	Decreasing	0.005
Hepatitis A	18.54	19.57	19.41	Increasing	0.65
Shigellosis	21.56	25.41	15.58	Decreasing	0.14

a/ Adjusted for age and sex using direct method, 1979-80 Los Angeles County population as standard.

b/ Weighted average of two control rates using inverse of variance as weight.

c/ Estimate of linear trend based on scoring of exposure to reclaimed water in study areas: northwest control area = 0, central control area = 0, low reclaimed water area = 1, and high reclaimed water area = 2.

d/ Level of statistical significance based on Mantel chi-square test for linear trend.

TABLE VII-21

COMPARISON OF BIRTH OUTCOMES OR DEATHS DURING THE FIRST YEAR OF LIFE AMONG TWO RECLAIMED WATER AREAS AND TWO CONTROL AREAS, 1979-80

Health Outcome	Control Areas						Reclaimed Water Areas						Significance P	
	Northwest			Central			Low (< 5%)			High (≥ 5%)				
	Number of Events	SR a/	DAR b/	Number of Events	SR a/	DAR b/	Number of Events	SR a/	DAR b/	Number of Events	SR a/	DAR b/	SR c/	DAR d/
Birth Outcomes														
Low weight births	823	0.83	52.17	225	0.75	47.75	775	0.85	53.71	211	0.80	50.58	NS	NS
Very low weight births	156	0.89	9.86	36	0.69	7.48	130	0.81	9.01	42	0.91	10.05	NS	NS
Death Outcomes														
Infant deaths	159	0.98	10.85	41	0.95	11.23	134	0.94	10.33	38	0.89	10.07	NS	NS
Neonatal deaths	107	1.01	7.44	30	1.12	8.33	80	0.88	6.25	29	1.04	7.82	NS	NS

a/ Standardized ratios; observed events in 1979-80 divided by expected events in 1979-80 based on Los Angeles County age of mother-specific rates of birth outcomes or age of mother- and birth weight-specific rates of death outcomes (SR for Los Angeles County = 1.0).

b/ Directly adjusted rates per 1,000 live births per year using 1979-80 Los Angeles County live birth population as standard (average annual low weight birth rate for Los Angeles County, 1979-80 = 63.29 births weighing < 2,500 gm per 1,000 live births; average annual very low weight birth rate for Los Angeles County, 1979-80 = 11.09 births weighing ≤ 1,500 gm per 1,000 live births; average annual infant death rate for Los Angeles County, 1979-80 = 11.09 infant deaths per 1,000 live births; average annual neonatal death rate for Los Angeles County, 1979-80 = 7.35 neonatal deaths per 1,000 live births).

c/ Level of significant difference among the SRs of the four areas; one way analysis of variance; NS = not significant ($P \geq 0.05$).

d/ Level of significant difference among the DARs of the four areas; Mantel-Haenszel nominal test of association; NS = not significant ($P \geq 0.05$).

very low weight births. As shown in Table VII-22, an increasing linear trend was observed for each birth outcome when adjusted for maternal age and maternal age and race; however, the trend was not statistically significant for any of the outcomes. Figures presenting the 1979-80 infant mortality rates and neonatal mortality rates for various weight-at-birth categories have been included in Appendix O. For the statistical analysis of infant and neonatal mortality, the data were adjusted for both weight at birth and age of the mother. As shown in Table VII-21, there were no statistically significant differences among the four areas. Both the SIMRs and DARs were lower than those for Los Angeles County, while the SNMRs were slightly lower or almost equal to the Los Angeles County ratios/rates. A further analysis, including adjustment for the race of the child, yielded similar results.

The final analysis of birth outcomes compared the high and low reclaimed water areas to the two control areas to determine if residence in the reclaimed water area was associated with an increase in either infant or neonatal mortality. As shown in Table VII-22, there was a slight decreasing, but not statistically significant trend for the outcome categories.

HOUSEHOLD SURVEY

As part of the third phase of the epidemiology study, a telephone survey was conducted among women in the study area to further test the hypothesis that consumption of reclaimed water had contributed to an increase in adverse health effects. The survey provided a wide variety of information not available from the previously evaluated vital statistics data sets. This included information on adverse reproductive outcomes such as miscarriages and spontaneous abortions, on general indicators of functional impairment such as restricted-activity days and bed-disability days and on the possible confounding effects of factors such as mobility, alcohol consumption, cigarette smoking and bottled water consumption.

The household sample was drawn from two distinct areas: those households receiving a high percentage of reclaimed water in their water supply (exposed) and those households receiving no reclaimed water (unexposed). Most of the respondents were contacted and interviewed by telephone in order to minimize the cost and length of time required to complete the survey. All aspects of the interview were administered in both English and Spanish by professional interviewers from the UCLA Institute for Social Science Research during January through April 1981.

The survey population was limited to women in order that as much data as possible could be collected on reproductive outcomes. In addition, it seemed reasonable to assume that women would have a higher average exposure to domestic water supplies than men. And finally, it was known that women, in general, were more willing than men to participate in a survey based on experience from similar studies. From a biological standpoint, it was assumed that if exposure to reclaimed water was found to have a detrimental effect on the health of women, then the causal associations (with the exception of reproductive disorders) could be generalized to men.

TABLE VII-22

ANALYSIS OF LINEAR TREND AMONG COMBINED CONTROL AREAS AND TWO RECLAIMED WATER AREAS, BIRTH-RELATED HEALTH OUTCOMES, 1979-80

Birth Outcome	Adjusted Rate per 1,000 Live Births per Year a/			Linear Trend c/	Significance d/ P
	Combined Control b/ Areas (0)	Reclaimed Water Areas			
		Low (1)	High (2)		
Adjusted for age of mother					
Low birth weight	51.10	53.71	50.58	Increasing	0.67
Very low birth weight	9.24	9.01	10.05	Increasing	0.88
Adjusted for age of mother and race					
Low birth weight	52.86	58.75	58.41	Increasing	0.51
Very low birth weight	10.03	9.50	12.00	Increasing	0.81
Adjusted for age of mother and birth weight					
Infant mortality	10.92	10.33	10.07	Decreasing	0.61
Neonatal mortality	7.56	6.25	7.82	Decreasing	0.58
Adjusted for age of mother, birth weight, and race					
Infant mortality	11.13	10.12	8.70	Decreasing	0.61
Neonatal mortality	8.19	6.67	5.22	Decreasing	0.53

a/ Adjusted for confounding variables using direct method, 1979-80 Los Angeles County live birth population as standard.
b/ Weighted average of two control area rates using inverse of variance as weight.
c/ Estimate of linear trend based on scoring of exposure to reclaimed water in study areas: northwest control area = 0, central control area = 0, low reclaimed water area = 1, and high reclaimed water area = 2.
d/ Level of statistical significance based on Mantel chi-square test for linear trend.

Survey Methods

Twenty-four census tracts were chosen as the target population for the household survey: eleven from the high reclaimed water area and thirteen from the central control area (see Figure VII-7). In terms of demographic characteristics, (based on the 1970 U.S. Census), the two sets of census tracts were fairly similar as indicated in Table VII-23. Each of the study areas contained approximately 60,000 people, of which over 98 percent were white and less than one percent black. However, the population living in the reclaimed water area contained more Hispanics (Spanish-surname and/or language spoken at home) than did the control area. The socioeconomic status of individuals living in the control area was, in general, higher than that of the reclaimed water area; the control area population contained a slightly higher percentage of employed persons classified as professional workers, a slightly higher percentage having completed high school, and a slightly lower percentage living in rental units. In terms of stability, the two populations were comparable with approximately 60 percent residing at the same address for at least five years.

In order to sample the population, every street segment located within the boundaries of the 24 census tracts was identified using two 1980 street address directories (VII-30, VII-31). Approximately 28,000 household addresses were listed in the specified street segments from which a systematic sample of 4,004 addresses was drawn using a random start.

Most of the addresses listed contained the name and telephone number of the resident. If a number was available, the interviewer contacted the residence. After completion of a screening questionnaire, the interviewer chose the respondent, using the random selection procedure of Kish (VII-32). If the respondent was available at the time of the call, the interview was conducted. If not, the interviewer arranged to call back at a more convenient time. If the telephone number listed in the directory was not correct, i.e., the address of the person with a particular telephone number did not match the address in the directory, an interviewer visited the household in person. At that time, the screening questionnaire was completed, the respondent chosen, and if possible, the interview was conducted in person. If the respondent was not available for the interview, a telephone number was obtained for later contact, and the interview was conducted by telephone.

For each address for which there was no name or telephone number listed in the directory, a letter explaining the purpose of the study was mailed to "Resident" at that address. Within two weeks of the mailing, an interviewer visited the household, administered the screening questionnaire, selected the respondent, and conducted the interview, if possible. If not, the telephone number was obtained and the interview was conducted at a later time by telephone.

Interviewers attempted to contact each household at least four times before it was classified in the nonresponse category. At least one call (telephone or home visit) was made during daytime hours on a weekday, at least one call was made during evening hours on a weekday, and at least one call was made during daytime hours on a weekend. The participation rate in the survey was either 71 percent (using all households as the target population) or 78 percent (using all

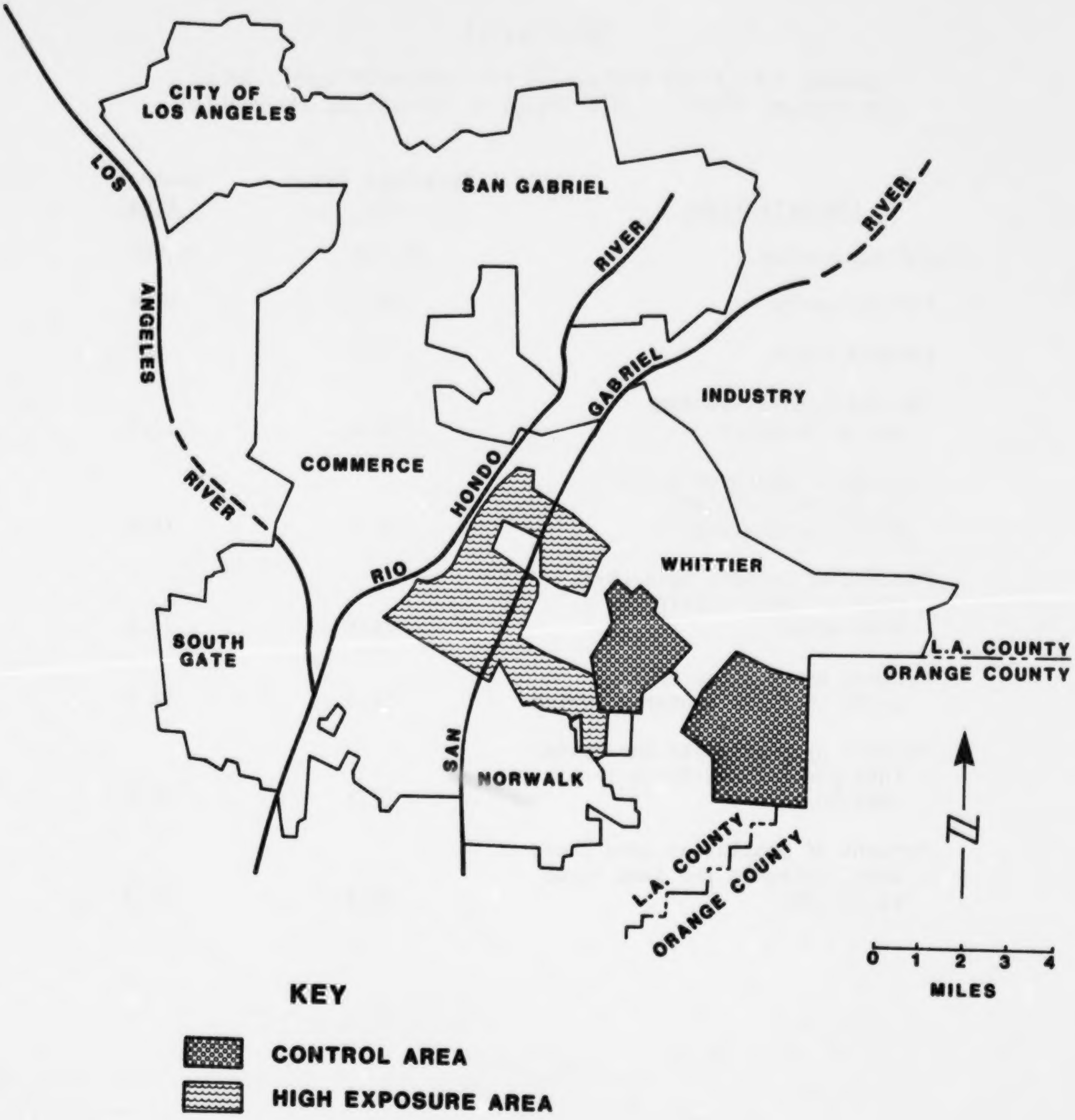


FIGURE VII-7
LOCATION OF AREAS USED IN 1981 HOUSEHOLD SURVEY

TABLE VII-23

GENERAL POPULATION STATISTICS FOR COMMUNITY SURVEY AREAS LOS ANGELES COUNTY - 1970 CENSUS OF POPULATION AND HOUSING

Characteristic	Reclaimed Water Area	Control Area
Total population	64,166	56,600
Percent white	98.3	98.4
Percent black	0.1	0.0
Percent Spanish-surname and/or language	32.9	17.5
Percent of employed persons 16 and over who are professional workers	11.2	14.8
Percent of persons aged 18-24 with at least 4 years of high school	69.1	75.9
Percent of occupied housing units that are renter-occupied	22.8	21.7
Percent of population who moved into present residence in 1969-70	17.2	17.4
Percent of population aged 5 and over living in the same house as in 1965	61.9	59.3

households with an identified adult woman as the target population), with the levels being nearly identical in the two study areas. A total of 2,523 women were surveyed; 1,243 women from the reclaimed water area and 1,280 women from the control area.

The majority of telephone interviews were conducted using an on-line computerized data collection system (Telephone Survey Management). A small percentage of the interviews were conducted by telephone using the booklet form of the questionnaire (without the computer system) as were the in-person interviews. All of the English versions of the letters and forms used for the survey have been included in Appendix P.

Statistical Methods

A chi-square test of independence was performed on the distribution of characteristics and health outcomes by study area using the Statistical Analysis System (SAS) package (VII-22). A two-tailed t-test was used to determine if there was a significant difference between the exposed and control areas in average daily consumption of water (bottled, tap, and combined), restricted-activity days, bed-disability days, hospital-bed days, and consultations for medical problems, all occurring during the past two months (VII-33). Assuming a Poisson distribution, a two-sided F-test (VII-34) was used to determine if there was a significant difference between the two areas in rates of several reproductive outcomes (total pregnancies, current pregnancies, prenatal deaths and live births). A test for difference between proportions was used to compare the proportions of pregnancies resulting in prenatal death (spontaneous or induced) or live births (VII-33).

With various health outcomes (restricted-activity days, bed-days, hospital-bed days, and medical consultations) as the dependent variables, stepwise multiple linear regression analyses (VII-16) were performed for the following set of independent variables: age, education, employment status, smoking status, alcohol consumption, ethnicity and area of residence. The regression analyses were repeated for two groups: all surveyed women and a subset who had lived at their current address five or more years and had consumed tap water on a daily basis at home. The first five independent variables were allowed to enter into each multiple linear regression, followed by ethnicity; area of residence was then entered at the last step.

Stepwise linear discriminant function analysis (VII-16) was used to distinguish between groups of women with and without a specific characteristic or health outcome. The grouping variables included self-reported health status, infertility, menstrual problems and congenital defects. Analyses were performed for one group containing all surveyed women and a second group containing all women who had lived at their current address five or more years, and had consumed tap water at home. Age, education, employment status, smoking status and alcohol consumption were forced into the discriminant function: ethnicity was then entered in a separate step, followed by area of residence as the last step. In addition to these seven variables, number of pregnancies in the past five years was included as a variable in the linear discriminant function (in a step preceeding ethnicity), in the analysis of menstrual problems, and in an analysis of congenital defects.

Results of the Survey

The demographic and socioeconomic characteristics of the surveyed women are shown in Table VII-24. When comparing the 1,243 women sampled from the reclaimed water area with the 1,280 women from the control area, there were no significant differences between the two groups in their age structure, marital status or employment. The two areas did differ significantly, however, in their racial-ethnic characteristics, with the reclaimed water area having nearly twice as many Hispanics as the control area and substantially fewer whites. Additionally, the educational level was somewhat lower in the exposed area than the control area, with a higher proportion of women having not completed high school and a lower proportion with college experience.

Variables which would have had an effect on exposure to drinking water are displayed in Table VII-25. Comparisons of the exposed and control areas indicated that there were statistically significant differences in the number of years the women lived at their present address. The women in the exposed area appeared to be somewhat less mobile than the women in the control area. Additionally, a higher proportion of women in the exposed area reported that they bought bottled water; 28 percent for the exposed area versus 24 percent for the control area. About a fifth of the interviewed women stated that they did not drink tap water.

Questions were also asked regarding daily home water consumption rates. Based on the responses, it appeared that women in both survey areas consumed about one liter of water per day in their households, with the consumption rate slightly less in the exposed area. On the average, women in both areas reported drinking almost a quarter of a liter of bottled water per day.

With respect to alcohol consumption (see Table VII-25) there was a significant difference between the two areas with the control area having a slightly higher proportion of women who stated that they consumed at least some alcohol. As indicated in Table VII-25, more than a quarter of the women reported that they currently smoked cigarettes; there were no apparent differences between the two areas. As also shown in Table VII-25, questions were asked about the attitude of the women towards their physical and social environment. Women were slightly less satisfied with their community environment in the reclaimed water area compared to the control area. When asked specifically about attitudes towards air and water quality, the responses by women in both areas were very similar with over half of the responses being favorable.

Self Reported Morbidity and Health Status. Several general measures of health status were used in the survey including restricted-activity days, bed-disability days, hospital-bed days, consultations for medical problems and personal assessment of health problems. These findings have been presented in Table VII-26. When comparing the exposed area to the control area, there were no apparent differences in any of the self reported health measures except for responses for personal health assessment. As indicated in Table VII-26, a higher proportion of women in the exposed area rated their overall health as poor or fair (20 percent versus 16 percent); yet when asked the question concerning disability status, a higher proportion of women in the control area stated that they currently were limited in their work or other activities by a health condition.

TABLE VII-24

DEMOGRAPHIC AND SOCIOECONOMIC CHARACTERISTICS OF SURVEYED WOMEN
JANUARY - APRIL 1981

Characteristic	Reclaimed Water Area N[a]	Reclaimed Water Area %	Control Area N[a]	Control Area %	Significance[b] P
Age (years)					NS
18 - 24	140	11.3	141	11.0	
25 - 44	526	42.3	560	43.8	
45 - 64	442	35.6	431	33.8	
≥ 65	134	10.8	145	11.4	
Race-ethnicity					<0.001
White	713	57.5	993	77.8	
Hispanic	479	38.6	237	18.5	
Other	48	3.9	47	3.7	
Marital Status					NS
Never married	125	10.1	112	8.8	
Married	916	73.7	972	75.9	
Other	(202)[c]	(16.2)	(196)	(15.3)	
Divorced	81	6.5	80	6.3	
Separated	10	0.8	17	1.3	
Widowed	111	8.9	99	7.7	
Education					<0.001
<High School	317	25.5	226	17.7	
High School	560	45.1	528	41.3	
Some College	259	20.9	381	29.8	
College or Postgraduate	105	8.5	144	11.2	
Employment Status					NS
Employed	635	51.1	651	50.8	
Not employed	(608)	(48.9)	(629)	(49.2)	
Homemaker	416	33.5	418	32.7	
Retired	121	9.7	143	11.2	
Other	71	5.7	68	5.3	

[a] N = number of responses.

[b] Level of significant difference between the two areas, x^2 analysis; NS = not significant ($P>0.05$).

[c] Numbers in parenthesis excluded from analysis.

TABLE VII-25

ENVIRONMENTAL CHARACTERISTICS OF SURVEYED WOMEN
JANUARY - APRIL 1981

	Reclaimed Water Area		Control Area		Significance[b]
Query	N[a]	%	N[a]	%	P
Years at present address?					<0.01
<1	85	6.8	97	7.6	
1 - 4	305	24.6	380	29.7	
5 - 10	317	25.5	330	25.8	
>10	535	43.1	473	36.9	
Buy bottled water?[c]					<0.05
No	893	71.8	967	75.6	
Yes	350	28.2	313	24.4	
Drink tap water?[d]					NS
No	283	22.8	250	19.5	
Yes	960	77.2	1030	80.5	
Consume alcoholic beverages?					<0.05
No	443	35.6	406	31.7	
Yes	800	64.4	874	68.3	
Smoke cigarettes?					NS
No	930	74.8	932	72.8	
Yes	313	25.2	348	27.2	
Attitude towards community?					<0.01
Satisfied	1065	85.9	1149	89.9	
Not satisfied	175	14.1	129	10.1	
Attitude towards air quality?					NS
Good	724	58.5	740	58.1	
Not Good	514	41.5	533	41.9	
Attitude towards water quality?					NS
Good	754	61.2	808	64.0	
Not Good	479	38.8	454	36.0	

---

[a] N = number of responses.

[b] Level of significant difference between the two areas, for all questions other than water consumption, x^2 analysis; for water consumption questions, t-test; NS = not significant ($P > 0.05$).

[c] Bottled water consumption (liters/day): $\bar{x} = 0.27 \pm 0.54$ for reclaimed water area and $\bar{x} = 0.25 \pm 0.55$ for control area ($P > 0.05$).

[d] Tap water consumption (liters/day): $\bar{x} = 0.81 \pm 0.68$ for reclaimed water area and $\bar{x} = 0.90 \pm 0.77$ for control area ($P < 0.01$); total water consumption (liters/day): $\bar{x} = 1.08 \pm 0.62$ for reclaimed water area and $\bar{x} = 1.16 \pm 0.71$ for control area ($P < 0.01$).

TABLE VII-26

SELF-REPORTED MORBIDITY AND HEALTH STATUS AMONG SURVEYED WOMEN IN RECLAIMED WATER AND CONTROL AREAS
JANUARY - APRIL 1981

Query	Reclaimed Water Area		Control Area		Significance[b]
	N[a]	%	N[a]	%	P
Any bed-days in past 2 months?					NS
No	918	73.9	938	73.3	
Yes	325	26.1	342	26.7	
Number of bed-days.					NS
1	98	30.2	103	30.1	
2	77	23.7	75	21.9	
≥3	150	46.1	164	48.0	
Any restricted-activity days in past two months?					NS
No	755	60.7	771	60.2	
Yes	488	39.3	509	39.8	
Number of restricted-activity days.					NS
1	89	18.2	89	17.5	
2	94	19.3	94	18.5	
≥3	305	62.5	325	64.0	
Any contact with health professional in past two months?					NS
No	905	72.8	896	70.0	
Yes	338	27.2	384	30.0	
Any hospitalizations in past two months?					NS
No	1206	97.0	1245	97.3	
Yes	37	3.0	35	2.7	
Personal assessment of health status.					<0.01
Excellent/good	992	79.9	1079	84.4	
Fair/poor	249	20.1	199	15.6	
Personal assessment of disability status.					<0.001
Not disabled	1087	87.4	1055	82.4	
Disabled	156	12.6	225	17.6	

---

[a] N = number of responses.

[b] Level of significant difference among the two areas, x^2 analysis; NS = not significant (P>0.05).

When the study areas were divided into those who reported consuming tap water versus those who had reported consuming bottled water, there were no significant differences between the two areas in the average number of restricted-activity days, bed-disability days, hospital-bed days, or medical consultations. The only statistically significant difference was observed among bottled water users with the control area having a higher medical consultation rate than the reclaimed water area.

While there appeared to be no differences attributable to consumption of reclaimed water in the various health measures considered, it was possible that any real differences could have been obscured by subtle differences between the two areas in factors such as age, race-ethnicity, education, employment status, smoking habits, or alcohol use. To adjust for the potential confounding effects of these factors, multiple linear regression analyses were conducted, the results of which are shown in Table VII-27. For restricted activity days, there was no residual significant association between residence in the reclaimed water area and the health outcome. In fact, the regression coefficient for the residence variable was slightly negative, indicating that the women in the reclaimed water area had fewer restricted-activity days after accounting for the other variables than did the women in the control area. This slightly negative association, however, might well have been due to chance. Results were similar for the other three outcome measures evaluated: bed-disability days, hospital-bed days, and medical consultations.

Because the lack of an association between residence in the reclaimed water area and the self reported health measures might well have been due to the confounding effects of mobility or bottled water usage, a subsequent regression analysis was conducted which was limited to those women who had lived at their present address for five or more years and who had reported that they consumed tap water. A total of 1,302 women fitted into this category. Results of the analysis indicated that residence in the reclaimed water area was not significantly related to any of the health outcomes after controlling for the effects of these confounding variables.

Having demonstrated that a higher proportion of women in the reclaimed water area as compared to the control area rated their overall health as fair or poor, a linear discriminant function analysis was conducted comparing those women who reported their health status to be excellent or good with women who reported their health status to be fair or poor. The same variables used in the linear regression analysis were included in the discriminant function analysis. As indicated in Table VII-28, women who reported their overall health status as excellent or good were statistically different from those women who reported it to be fair or poor in terms of age structure, level of education, employment status, race-ethnicity, smoking behavior and in the level of moderate alcohol consumption. After these factors were accounted for, it appeared that self reported health status was unrelated to living in the reclaimed water area. The analysis was repeated on only those women who had lived at the same address for five or more years and who had consumed tap water. Results indicated that residence in the reclaimed water area still did not contribute significantly to the discrimination between the two health status groups.

Reproductive Outcomes. The survey also included questions about various reproductive outcomes. Women were asked if there was a time in the last five

TABLE VII-27

MULTIPLE REGRESSION ANALYSIS OF SELECTED HEALTH OUTCOMES AMONG SURVEYED WOMEN JANUARY - APRIL, 1981 (N = 2,523)

Multiple Linear Regression Coefficients [a]

Outcome variable	Intercept	Age (years)	Education (years)	Employed (0,1)	Smoker (0,1)	Moderate use of alcohol (0,1)	White (0,1)	Reclaimed water area (0,1)	Multiple R^2
Restricted-activity days [b]	3.539	0.056[f]	-0.002	-3.268[f]	0.247	-0.448	0.208	-0.255	0.034
Bed-disability days [c]	2.274	0.005	-0.011	-1.125[f]	0.226	-0.821	-0.180	-0.334	0.014
Hospital-bed days [d]	0.289	0.001	-0.007	-0.180[f]	-0.045	0.009	0.008	-0.021	0.008
Medical consultations [e]	1.073	0.001	-0.022	-0.303[g]	0.130	-0.041	0.212	-0.046	0.008

[a] Location of residence: 0 = control area, 1 = reclaimed water area.

[b] 15 nonresponses.

[c] 14 nonresponses.

[d] 20 nonresponses.

[e] 17 nonresponses.

[f] Significant at $P < 0.001$.

[g] Significant at $P < 0.01$.

TABLE VII-28

DISCRIMINANT FUNCTION ANALYSIS OF SELF-REPORTED HEALTH STATUS AMONG SURVEYED WOMEN, JANUARY - APRIL, 1981

	Self-reported health status		
	Excellent/good (N=2,061)[a]	Fair/poor (N=445)[a]	Significance[b]
Variable	$\overline{X}$	$\overline{X}$	P
Age (years)	42.6	48.6	< 0.001
Education (years)	12.4	10.7	< 0.001
Employed (%)	55	32	< 0.001
Cigarette smoking (%)	26	27	NS
Moderate alcohol consumption (%)	8	4	< 0.05
White (%)	70	57	< 0.001
Reclaimed water area (%)	48	56	NS

a/ N = number of responses.

b/ Level of significance among the two health status groups, F test; NS = not significant (P >0.05).

years when they had tried to become pregnant and either could not do so or took more than six months to do so, and if during the last five years they had seen a doctor about menstrual problems. Other questions were related to number of pregnancies, prenatal deaths, live births and congenital malformations occurring in the last five years.

As indicated in Table VII-29, there were no significant differences among the exposed and control areas in terms of the various reproductive outcomes with one exception; the control area had a higher average number of spontaneous abortions (37 percent) than the exposed area (26 percent). When broken down according to tap water or bottled water usage, the results were the same. To determine if this may have been due to differences in the age structure between the two populations, the rate of spontaneous abortion was evaluated by age. As indicated in Figure VII-8, the control area, with the exception of the youngest age group consistently exhibited a higher spontaneous abortion rate than that of the reclaimed water area.

Linear discriminant function analyses were conducted for three health outcomes: infertility, menstrual problems, and congenital defects. In each case, women who had reported having a given problem were compared with the remaining women surveyed. The results are shown in Table VII-30. For each reproductive outcome, residence in the reclaimed water area did not contribute to the discrimination between groups of women with and without the stated problems. Subsequent analyses which were limited to those women who had lived at the same address five or more years and who had consumed tap water yielded similar results.

SIMULATION MODEL

With the possible exception of deaths due to rectal cancer, the vital statistics analyses and telephone survey portions of the study suggested that the groundwater recharge practice had not resulted in any measurable harmful effect to the consuming public. While reassuring, this did not necessarily mean that for most conditions there were no excess cases of disease caused by drinking contaminated water. Rather, it indicated that if there were excess cases, their numbers were below levels that could be measured by this particular type of investigation. Such factors as high migration rates, low consumption of tap water, or the presence of contaminants that caused only sub-chronic or latent health effects, could all have mitigated the likelihood of a population-based study observing excess disease. To provide insight into the limitations of the investigation, a computer simulation model was developed (VII-35, VII-36) to replicate the study population and determine the theoretical effects, based on animal models, of exposure to various contaminants.

Description of the Model

The simulation model was developed to determine if low dose exposures to reclaimed water could theoretically produce an increase in a specified health outcome which could be detected in an epidemiologic study of the community. Specifically, the model was used to determine the expected disease rate in the community exposed to a known amount of some contaminant and to test the disease rate if the concentration of the contaminant changed, if the exposure dose was

TABLE VII-29

REPRODUCTIVE OUTCOMES AMONG SURVEYED WOMEN AGED 18-44 YEARS IN RECLAIMED WATER AREA AND CONTROL AREA JANUARY - APRIL, 1981

Variable	Reclaimed Water Area		Control Area		Significance[b]
	N[a]	%	N[a]	%	P
Any problem of infertility during the past 5 years?					NS
No	624	93.7	654	93.3	
Yes	42	6.3	47	6.7	
Any problem with menstrual periods during the past 5 years?					NS
No	542	81.4	547	78.0	
Yes	124	18.6	154	22.0	
	$\bar{x} \pm$ S.D.		$\bar{x} \pm$ S.D.		
Pregnancies in past 5 years [c]	0.59 ± 0.80		0.60 ± 0.94		NS
Prenatal deaths in past 5 years					
Spontaneous	0.06 ± 0.26		0.08 ± 0.37		<0.05
Induced	0.05 ± 0.27		0.04 ± 0.21		NS
Live births in past 5 years	0.45 ± 0.67		0.42 ± 0.69		NS
Congenital malformations in past 5 years	0.02 ± 0.13		0.01 ± 0.13		NS

[a] N = number of responses.

[b] Level of significant difference between two areas; x^2 analysis; F test for two Poisson means; NS = not significant ($P > 0.05$).

[c] Includes current pregnancies.

FIGURE VII-8
SPONTANEOUS ABORTIONS IN PAST FIVE YEARS
BY AGE AND STUDY AREA, 1981

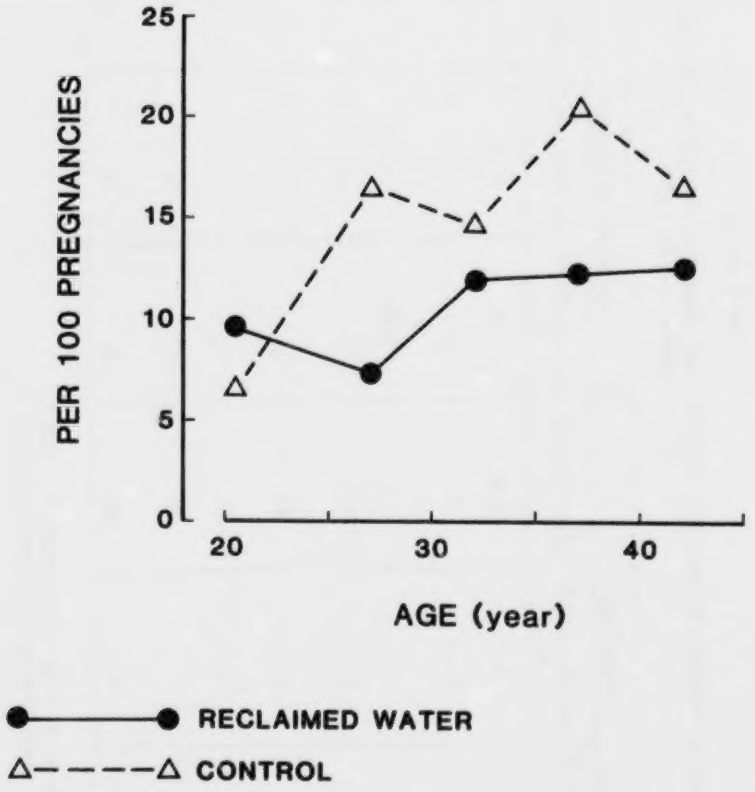


TABLE VII-30

DISCRIMINANT FUNCTION ANALYSIS OF INFERTILITY, MENSTRUAL PROBLEMS, AND CONGENITAL DEFECTS IN THE PAST FIVE YEARS AMONG SURVEYED WOMEN, AGED 18-44 YEARS, JANUARY - APRIL, 1981

Variable	Infertility			Menstrual Problems c/			Congenital Defects c/		
	Yes (N=89) a/ x	No (N=1,274) a/ x	Significance b/ P	Yes (N=277) a/ x	No (N=1,086) a/ x	Significance b/ P	Yes (N=18) a/ x	No (N=519) a/ x	Significance b/ P
Age (years)	29.3	31.0	< 0.05	31.2	30.9	NS	30.7	28.6	NS
Education (years)	12.5	12.5	NS	12.5	12.4	NS	13.5	12.2	NS
Pregnancies (in past 5 years)	-	-	-	0.58	0.60	NS	1.5	1.5	NS
Employed (%)	47	63	< 0.01	60	62	NS	33	48	NS
Cigarette Smoking (%)	22	27	NS	34	26	< 0.05	28	22	NS
Moderate alcohol consumption (%)	4	8	NS	9	7	NS	0	4	NS
White (%)	54	57	NS	61	56	NS	78	49	< 0.05
Reclaimed water area (%)	47	49	NS	45	50	NS	50	52	NS

a/ N = number of responses.
b/ Level of significance, F test; NS = not significant ($P > 0.05$).
c/ Health problem reported by women with at least one pregnancy.

at a different level, or if the same environmental concern arose in a different sized community. The evaluation of a particular situation was based on a comparison of the observed disease incidence rate (as predicted by the model) to the expected rate had the exposure not been present.

The basic structure of the model consisted of three units: 1) demographic characteristics, 2) components related to the anticipated disease outcome, and 3) environmental and behavioral conditions. The specific variables have been listed in Table VII-31. The demographic variables included the population age distribution, the distribution of death rates and fertility rates, and other data necessary to determine the natural growth of population over the selected projection period. Information was obtained from the U.S. Census and local vital statistics records. The disease-related components of the model included the nature of the disease, its frequency, and dose-response relationships of a given toxic exposure. Specifically, the model was designed to simulate the health effects associated with a progressively degenerating, nonreversible disease such as cancer. The low risk assessment technique used for the simulation was the one-hit or linear model (VII-37) which is considered the most conservative of the available extrapolation methods used to establish water quality standards (i.e., the EPA Water Quality Criteria) for contaminants showing evidence of carcinogenicity in man or other animals.

The simulation began by defining the exposed population in terms of the demographic and epidemiologic variables listed in Table VII-31, which were taken from the 1970 U.S. Census. Assuming that the population had been exposed to a contaminant in drinking water over a period of 24 years, dose-response data obtained from animal tests were used along with the epidemiological data on the background rate for the anticipated health outcome to determine the rate of disease given the exposure. Other assumptions included a 12-year latent period for onset of disease, an average consumption rate of 1.5 liters of water per day and exposure to a single compound. The simulated disease rate was compared to the background level to see if the exposure was sufficient to have caused a statistically significant increase.

Results of the Simulation Model

Outcomes of four diseases were tested in the simulation studies: cancer at all sites, cancer of the rectum, cancer of the liver, and congenital malformations. Four contaminants (dinitrotoluene, heptachlor, polychlorinated biphenyls and phthalate esters) were assumed to be present in the water of the modeled population. Of these, only the phthalate esters were actually found in the drinking water supplies of the study population (see Chapter IV). Given the water consumption levels and the migration habits of the people living in the area, the model estimated the effect these contaminants would have on the health status of the exposed population. Three of the contaminants, dinitrotoluene, heptachlor, and polychlorinated biphenyls, were tested as to their effects on the rates of cancer at all sites and of the rectum and liver, while the phthalate esters were related to congenital malformations.

Malignant Neoplasms. Three cancer outcomes were selected for evaluation to represent the frequency spectrum from "relatively common" to "rare." Cancer at all sites has an annual incidence rate of approximately 300/100,000 population

TABLE VII-31

COMPONENTS OF THE SIMULATION MODEL

DEMOGRAPHIC AND EPIDEMIOLOGIC VARIABLES

Age-,sex-, race-specific:

- Population distribution
- Migration rates
- Disease "X" incidence rates (no exposure)
- Death rates
- Fertility rates
- Sex ratio among newborns

Duration of follow-up period

Latent period for disease "X"

EXPOSURE VARIABLES

Daily consumption rate of contaminated water

Concentration of contaminant in the water supply

Body retention factor for the contaminant

STATISTICAL AND EXTRAPOLATION DATA

Duration of follow-up period for the simulation

Alpha -- significance level for statistical testing

Beta -- level used to determine power for the statistical testing

Animal-to-man dose conversion factor

Safety factor

Known dose-response for the extrapolation

Slope of the dose-response extrapolation curve

Method for determining age-specific disease rates from the lifetime probability of disease: multiplicative model

(VII-38) and is considered a relatively common disease. Cancer of the rectum, has an annual incidence of 13.6/100,000 population (VII-38) and is intermediate in frequency. The least common cancer, that of the liver, is very rare, with an annual incidence of only 2.2 cases per 100,000 population (VII-38).

The contaminants tested were chosen to be representative of the wide range of potencies found among animal (suspected human) carcinogens. Dinitrotoluene (DNT) was selected to represent a weakly potent carcinogen while heptachlor, a commonly used pesticide, was selected as the contaminant of intermediate potency. Polychlorinated biphenyls (PCBs) which belong to a class of organic compounds having widespread industrial use, were selected to represent a class of carcinogens of high potency. Differentiation between potencies was based on the results of animal toxicity tests and their application to human health effects (VII-35, VII-37, VII-39).

By basing the simulations on a linear risk model, the dose required of a specific toxic agent to produce a given level of disease followed an inverse relationship. The individual graphs for each cancer outcome are shown in Figure VII-9. Each graph contains four lines: a horizontal line depicting the expected rate of disease in the absence of exposure (background rate), and three curves which show the predicted rate of disease at different exposure levels for the three classes of potential carcinogens. For cancer of the rectum, since no specific causal agent had been hypothesized, the results were generalized to represent disease rates due to a single but unknown contaminant of high, moderate, or low potency.

The minimum rate of disease that must be achieved in the simulated groundwater recharge population to observe a statistically significant increase ($P < 0.05$) over the "no-exposure" rate is also shown in Figure VII-9. For all cancers as the outcome, a dose of 0.68 mg PCBs/kg/day ($\log_{10}$ dose = -0.17) yielded a significantly increased disease rate over the "no exposure" rate, while for liver cancer the dose would had to have been 7.41 mg/kg/day ($\log_{10}$ dose = 0.87), or more than ten times greater. Similar findings were noted for heptachlor with doses of 2.14 mg/kg/day and 25.7 mg/kg/day required to achieve a significant increase in all cancers and liver cancer, respectively. For DNT, the dose would have to have been 214 mg/kg/day to result in a statistically significant increase, while for cancer of the liver, no significant dose was obtained.

For cancer of the rectum in which three levels of toxicity were represented rather than the specific contaminants, the statistically significant doses for high and medium-level agents were 229.1 mg/kg/day ($\log_{10}$ dose = 2.4) and 741.3 mg/kg/day ($\log_{10}$ dose = 2.9), respectively (see Figure VII-9.). The curve for the low toxicity agent remained relatively flat, with no statistically significant increase observed in the range of doses between 0 and 1000 mg/kg/day.

The minimum dose required to produce the significant increases was divided into its two major components--the daily rate of water consumption and the concentration of contaminant in the water supply. In this manner, it was possible to gain some insight into the conditions and behaviors that would have to be present in the study area to permit detection of an increase in disease with some preset level of statistical assurance.

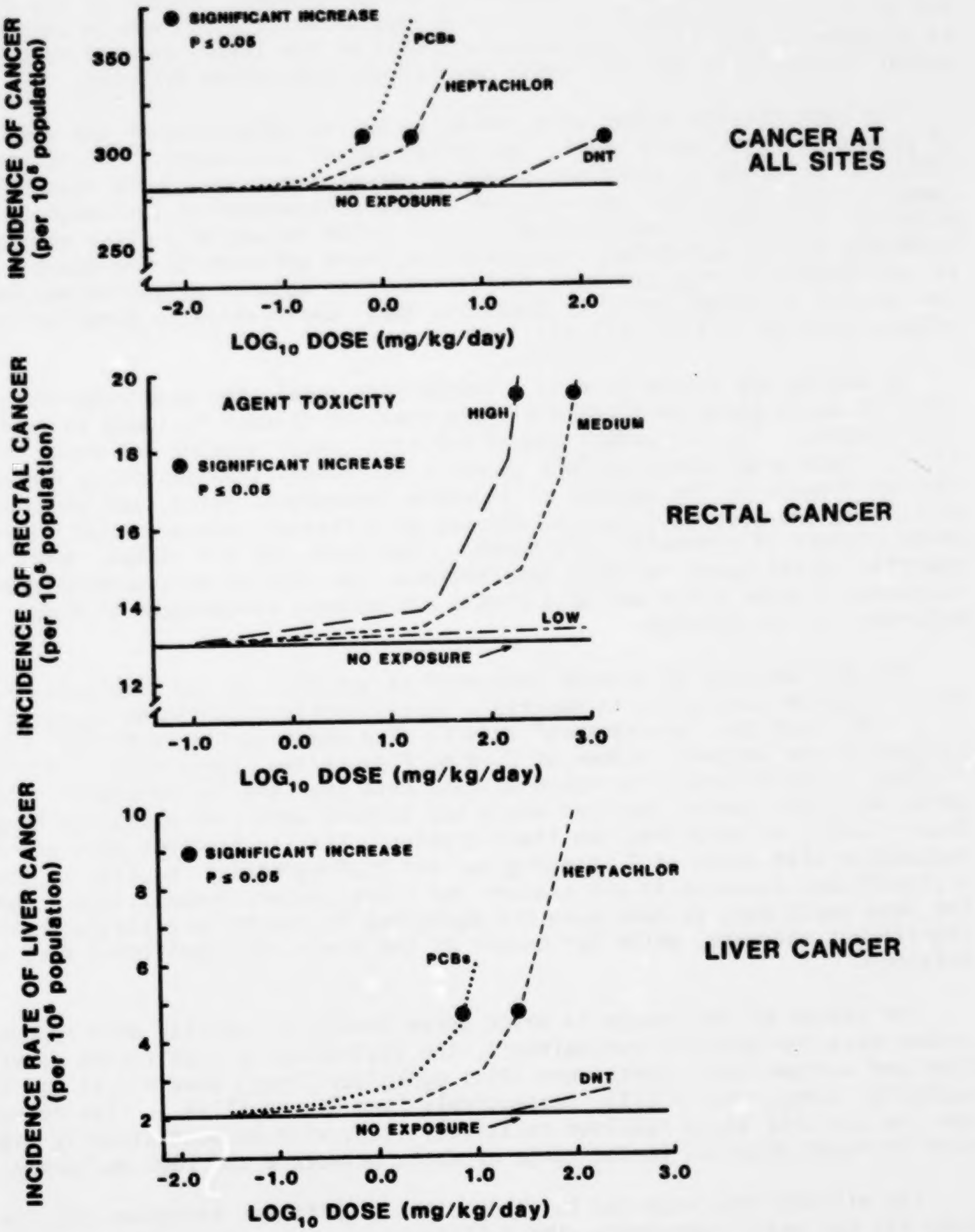


FIGURE VII-9 THEORETICAL DOSE RESPONSE RELATIONSHIP BETWEEN CARCINOGENS AND MALIGNANT NEOPLASM

GROUNDWATER RECHARGE POPULATION 24 YEARS OF EXPOSURE

Table VII-32 shows the results of the possible combinations of drinking water consumption and contaminant concentrations that would produce a statistically significant increase in the rate of cancer. For PCBs, given a consumption rate of 1.5 liters of water per day, a concentration of 32 mg/L would be required to produce a significant increase in the rate of all cancers while a concentration of 345 mg/L would be required to produce an increase in liver cancer. In another perspective, one water quality survey found the level of PCBs to be 0.003 mg/L. At this level, people in the reclaimed water area would have had to consume 16,000 liters of water per day to detect a statistically significant increase in the rate of all cancers and 170,000 liters per day for liver cancer. Similar results were observed for heptachlor and DNT. For cancer of the rectum the concentration of a very toxic agent or agents would have to be 10,700 mg/L to detect a significant increase assuming a water consumption rate of 1.5 liters/day (see Table VII-32).

These estimates were based on the assumption that water consumption was solely from a supply containing reclaimed water. However, the actual exposure could well have been reduced when considering such factors as consumption of tap water at work or school which would not have contained reclaimed water or consumption of bottled water. Furthermore, given the range of reclaimed water exposures (0 to 18 percent), the concentration of contaminants would have to have been orders of magnitude higher than the concentrations presented in Table VII-32 to produce significant increases in cancer rates above background cancer rates.

The effects of migration on the ability to detect a statistically significant increase in the rate of cancer were also evaluated. For this analysis, the in-migration and out-migration rates were assumed to be equal since a difference between them would have resulted in a change in the population size thereby confounding the effects of migration per se. Figure VII-10 illustrates the effects of migration on the minimum dose of PCBs required to produce a statistically significant increase in the rate of cancer. As indicated in Figure VII-10, the minimum dose increased as the migration rate increased. Assuming a consumption rate of 1.5 liters per day for a 70 kg adult, the minimum concentration of PCBs required to produce a significant increase in the rate of all cancers would have to have been 28 mg/L for an annual migration rate of 12 percent; for a stable population (zero percent migration), the same concentration would have to have been 14 mg PCBs/L.

Congenital Malformations. The simulation model was also used to predict rates of congenital malformations resulting from exposure to phthalate esters. For this analysis it was assumed that the dose-response curve for phthalate esters and congenital malformations could be described by the low-dose carcinogenic risk assessment model. This dose response curve which reflected the disease experience after ten years of exposure is shown in Figure VII-11. To detect a statistically significant increase, the rate of congenital malformations would have to have risen from 10/1000 live births (no exposure rate) to 14/1000 live births. At a dose of 2.1 mg/kg/day ($\log_{10}$ dose = 0.3) which corresponded to a 98 mg/L drinking water concentration for a 70 kg adult consuming 1.5 liters/day, only a three percent increase in the rate was calculated.

As reported in Chapter IV, phthalate esters were commonly found in all of the Montebello Forebay source waters tested. Concentrations of diethylhexyl

TABLE VII-32

THEORETICAL COMBINATIONS OF DRINKING WATER CONSUMPTION AND CONTAMINANT CONCENTRATION THAT WOULD PRODUCE A STATISTICALLY SIGNIFICANT INCREASE IN THE RATE OF CANCERa/

	All Cancers			Rectal Cancer			Liver Cancer		
	Dose Requiredc/ for Statistical Significance	Dose Relationship		Dose Requiredc/ for Statistical Significance	Dose Relationship		Dose Requiredc/ for Statistical Significance	Dose Relationship	
Contaminantb/	(mg/kg/day)	Consumption Rate (L/day)	Concentration (mg/L)	(mg/kg/day)	Consumption Rate (L/day)	Concentration (mg/L)	(mg/kg/day)	Consumption Rate (L/day)	Concentration (mg/L)
Very toxic: PCBs	0.68	0.5	95	229.09	0.5	32,000	7.4	0.5	1,040
		1.0	48		1.0	16,000		1.0	520
		1.5	32		1.5	10,700		1.5	345
		10.0	5		10.0	1,600		10.0	52
		1.6 x 10^{4}	3.0 x 10^{-3}d/		5.3 x 10^{6}	3.0 x 10^{-3}d/		1.7 x 10^{5}	3.0 x 10^{-3}d/
Toxic: Heptachlor	2.14	0.5	300	741.31	0.5	104,000	25.7	0.5	3,600
		1.0	150		1.0	52,000		1.0	1,800
		1.5	100		1.5	34,600		1.5	1,200
		10.0	15		10.0	5,200		10.0	180
		5.0 x 10^{7}	3.0 x 10^{-6}e/		1.7 x 10^{10}	3.0 x 10^{-6}e/		6.0 x 10^{8}	3.0 x 10^{-6}e/
Slightly toxic: DNT	214.28	0.5	30,000	No reasonable dose	-	-	No reasonable dose	-	-
		1.0	15,000		-	-		-	-
		1.5	10,000		-	-		-	-
		10.0	1,500		-	-		-	-

a/ Based on simulation of groundwater recharge exposure area.
b/ For all cancers and liver cancer, theoretical exposure to specific contaminants; for rectal cancer, theoretical exposure to very toxic or toxic agent or agents.
c/ Increase above background (P <0.05).
d/ Observed concentration in a drinking water survey (Reference VII-40).
e/ Observed concentration in a drinking water survey (Reference VII-41).

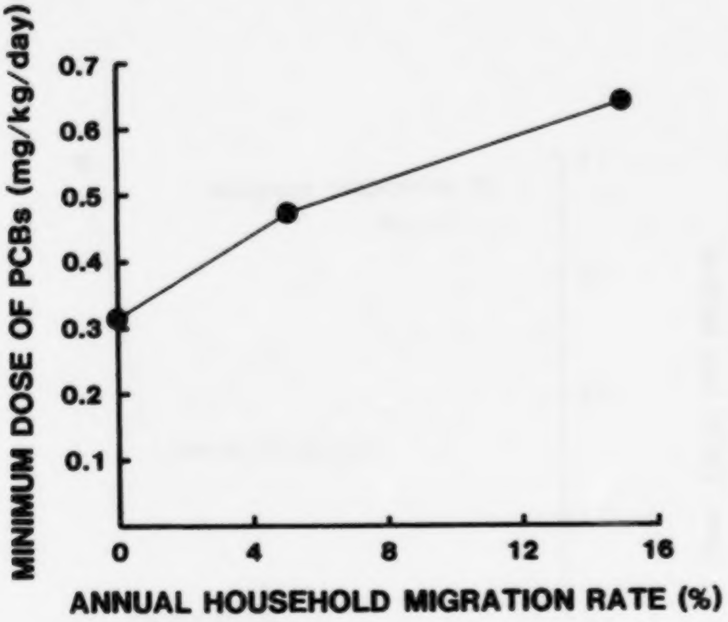


FIGURE VII-10 THEORETICAL EFFECT OF MIGRATION ON THE MINIMUM DOSE OF PCBs PRODUCING A SIGNIFICANT INCREASE IN CANCER

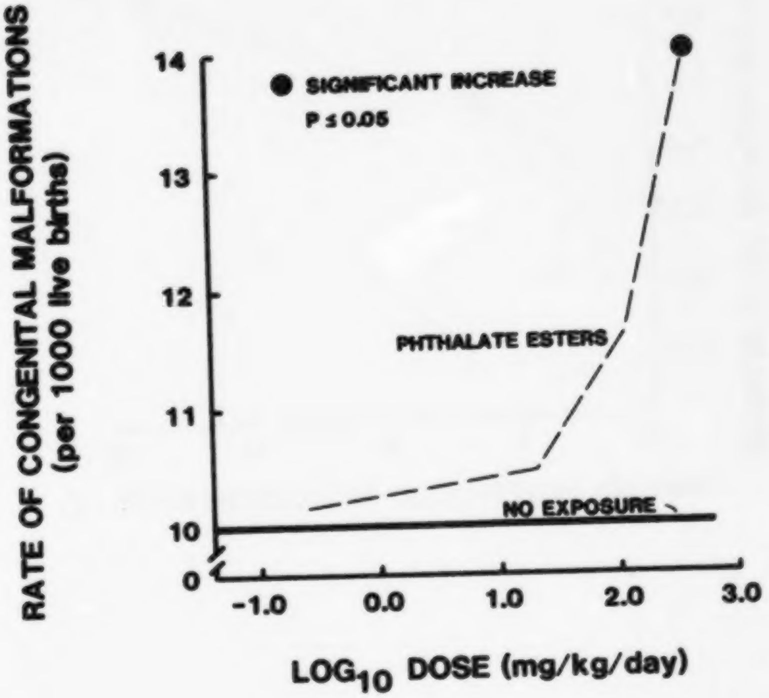


FIGURE VII-11 THEORETICAL DOSE-RESPONSE RELATIONSHIP OF PHTHALATE ESTERS AND CONGENITAL MALFORMATIONS (10 YEARS OF EXPOSURE)

phthalate ranged from 0.1 to 59 μg/L in the groundwater sampled while concentrations for the replenishment sources ranged from 1 to 13 μg/L for reclaimed water, 22 to 82 μg/L for storm water, and 0.3 to 168 μg/L for imported water. These results clearly indicated the ubiquity of phthalates in the drinking water of the study population. When evaluating the data using the simulation model, the highest dose required to produce a significant increase in congenital malformations above the no exposure level was 369 mg/kg/day ($\log_{10}$ dose = 2.57); this was at least four orders of magnitude greater than the observed concentrations assuming a water consumption rate of 1.5 liters/day.

DISCUSSION OF EPIDEMIOLOGIC RESULTS

Health and Vital Statistics Data. For the 1969-71 vital statistics analyses, significant differences in standardized ratios were observed among the reclaimed water and control areas for all potential waterborne diseases combined, infectious hepatitis, shigellosis, other potential waterborne diseases and congenital malformations. However, none of the observed relationships were in a direction suggesting that an agent in reclaimed water caused the disease. On the other hand, a tenable finding was arrived at for death due to malignant neoplasm of the rectum, with the standardized ratio being greatest in the high reclaimed water area, slightly less in the low reclaimed water area, and least in the control areas. There was a probability of 0.08 that the difference was due to chance. The implied relationship between water usage and rectal cancer might have been more credible biologically if cancers of the stomach or colon had exhibited a similar relationship.

The effects of such confounding variables as age, sex, birth weight and, when possible, race-ethnicity, were controlled for in the analyses. Unfortunately in the 1969-71 analysis of vital statistics data, it was not possible to control for other potential confounders such as smoking behavior, alcohol and drug use, dietary practices, marital status, employment status, or occupation, each of which might affect the inherent risk of the individual. Furthermore, it was not possible to account for the harmful effects of factors external to the individual such as air pollution or other forms of pollution from industrial or agricultural sources, although the proximity of the central control group to the reclaimed water areas should have minimized such discrepancies.

Finally, the length of time the population was exposed to reclaimed water was an important factor in the 1969-71 analyses. With respect to the communicable diseases and the birth-related outcomes, the incubation or induction period was relatively short and, therefore, was adequately represented in the investigation. However, for some of the chronic conditions, such as cancer, heart disease or strokes, a longer period of observation might have been necessary to detect an effect and even if this had been possible, any effect might well have been diminished by the mobility of the study population.

For the 1972-78 vital statistics data, the analyses of the mortality data suggested that with one exception, there were no differences between the four study areas that could be attributed to a contaminant in reclaimed water. Deaths due to cancer of the rectum for 1972-78 were found to be more in excess in the high reclaimed water area than in the low reclaimed water area, utilizing as a standard for comparison the proportionate mortality experience in the combined control areas. The low reclaimed water area had nearly the same number of deaths as expected, while the high reclaimed water area had 27 percent more deaths than expected. This figure must be interpreted with caution since the number of deaths was small and the excess was not consistent throughout the seven years of observation. The excess number of deaths, however, was statistically significant, with a probability of 0.03 that the finding was due to chance. With respect to cancer incidence, there were no significant differences observed between the reclaimed water areas and the control areas with the exception of cancer of the colon. However, in this case, the excess was in the control areas rather than the reclaimed water areas. When viewing the trend of cancer incidence over the seven-year period, there was no indication that the levels of the various cancers were increasing in the reclaimed water areas.

The 1972-78 analyses also included comparisons of the patterns of various potential waterborne diseases among the four study areas. Because there was no accurate information on the underlying population of interest, only a crude analysis was conducted which consisted of comparing the number of cases each year as a percentage of the average annual number of cases during 1969-71. While for each of the disease outcomes there might have been an excessive number of cases in the high reclaimed water area during the first half of the study interval, the findings could not be statistically tested to determine if they could have been due to chance. Nevertheless, during years 1976-78 when the reclaimed water exposure had increased to its greatest level, there was no discernible difference noted in the relative level of cases among the four study areas.

Finally, for the birth-related health outcomes, the 1972-78 analyses indicated that the combined reclaimed water areas had more events than expected relative to the control areas. These included infant deaths, neonatal deaths and very low weight births. In each of these instances, however, the low reclaimed water area had more excessive events than the high reclaimed water area, a finding that did not support the hypothesized dose-response relationship between reclaimed water consumption and disease. It was possible that there was a threshold above which the contaminants in the drinking water would have had harmful effects. Following this line of reasoning, the low and high reclaimed water areas would have had more excess events than either of the control areas, although the excess might not have been larger in the high area than in the low area. For the three health outcomes mentioned above, the results did not appear to be related to a threshold effect, since in each instance the low reclaimed water area had an excess number of events while the experience of the high reclaimed water area was similar to that of the two control areas.

For the 1979-80 vital statistics analyses, an increasing linear trend was observed for seven of nine death categories. For only two, however, were these trends statistically significant: death due to all causes and the summary category, death due to all other causes. In both instances, the rate in the high reclaimed water area was lower than the rate in the low reclaimed water area, suggesting that the increasing trend was not due to reclaimed water per se. For the four malignant neoplasms, the analysis of incidence data for 1979-80 indicated that the reclaimed water areas had slightly lower rates than the control areas. One of the decreasing trends, that of malignant neoplasm of the rectum, was statistically significant. Since this same cancer type had been incriminated in the 1969-71 and 1972-78 analyses, it is of interest to note that the most sensitive indicator -- namely the onset of incident rectal cancer cases nearly two decades after exposure was initiated -- provided no reason for concern that exposure to reclaimed water was having a detrimental effect on the level of rectal cancer in the population.

While the induction period between the initial exposure and the onset of disease may be quite long for some diseases such as cancer, for other conditions it should be of much shorter duration. Included in this latter group are birth-related outcomes (i.e., low and very low weight births and neonatal and infant mortality) and the infectious diseases. During 1979-80, the adjusted rates for both neonatal and infant mortality tended to be lower in the reclaimed water areas than in the control areas. For the low and very low weight births, however, the opposite occurred, with rates tending to be slightly greater in the reclaimed water areas than in the control areas. None of the increasing linear trends were statistically significant, suggesting that the slight trend observed was probably due to chance. For the potential waterborne diseases, the reclaimed water areas tended to have lower rates than the control areas with the exception of hepatitis A, which exhibited a slight, but not statistically significant, increasing trend.

Household Survey. To further clarify the actual level of exposure and the effects of confounding factors, and to assess their effect on other more subtle health outcomes, a household survey among women in the exposed and control areas was conducted. Simple comparisons between all women in the two study areas demonstrated that there were no significant differences in any of the measured health indices. Other analyses attempted to address the issue of exposure to reclaimed water by comparing women who consumed tap water in the exposed area with women who consumed tap water in the control area (since some reported drinking only bottled water). The analyses were further restricted by comparing the subgroups of women in the two areas who consumed at least some tap water at home and who had lived at their present address for five years or longer. It was felt that these women would have the maximum opportunity for exposure, even though there was concern that they might be different from the remainder of the population. For example, they might have been less health-conscious than those women who consumed bottled water or they might have been more healthy than those women who moved more often. This possible selection bias was the reason for limiting the analysis to the sub-groups of women in both areas rather than only in the reclaimed water area. Again, there was no significant difference between these two groups in any of the measured health outcomes.

Another concern addressed by the survey was that the women in the reclaimed water area and in the control area might differ in other characteristics that would affect their health, even in the absence of exposure to some potentially harmful agent. For example, if women in the reclaimed water area smoked more than women in the control area, a higher rate of various health conditions might occur in the reclaimed water area due to the harmful effects of smoking. To control for potentially confounding factors such as smoking, the data were analyzed by multivariate techniques. A series of stepwise analyses were performed in which the potentially confounding factors were first controlled by residence in the reclaimed water area to determine if exposure was associated with a higher rate of disease. This comparison was made between all women in the two areas and between the subgroups of women who consumed some tap water and who had lived at the same address for at least five years. None of these analyses provided evidence for an adverse effect due to reclaimed water.

In general, the levels of health observed for the surveyed women tended to be of the same magnitude as those reported in other studies using similar questions. For restricted-activity days, the finding of 4.3 days per two months was similar to 4.6 days (converted from 6.9 days per three months) reported by women in the Health Interview Survey (VII-42), a probability sample of the United States population. For bed-disability days, the survey reported 1.5 days per two months as compared to 1.7 days (converted from 2.6 days per three months) stated in the Health Interview Survey (VII-42). Moreover, the result showing 26 percent of the women reporting one or more bed-disability days was nearly identical to the 24 percent of women with the same statistic (both during the past two months) noted in a recent sample survey of Los Angeles County adults (VII-43).

Nearly 29 percent of the women in the present investigation contacted a health professional during the previous two months for a health problem as compared to 34 percent in the Los Angeles County survey (VII-43). The findings were equally close for hospitalizations in the past two months, with 3 percent having been hospitalized in the present study as compared to 5 percent in the Los Angeles County sample (VII-43).

Twenty-six percent of the interviewed women reported using bottled water in their homes; this figure was very similar to an estimate of 25 percent for Los Angeles County residents cited in a 1981 newspaper article (VII-44). The result of 26 percent current smokers compared favorably with other survey results: 31 percent of adult women in Los Angeles County (VII-45) and 30 percent of adult women in a national survey (VII-46).

The findings of 11 spontaneous abortions per 100 pregnancies and 10 induced abortions per 100 live births were in general agreement with 10 to 11.5 spontaneous abortions per 100 pregnancies and 18 induced abortions per 100 live births reported elsewhere (VII-47). Furthermore, the rate of 0.8 percent stillbirths as a percentage of all births was comparable to the reported rate in the literature of 1.25 percent (VII-47).

Based on these comparisons, it would appear that the women in the survey responded to the telephone interview much as would be expected. While a bias in the questionnaire would have affected both the reclaimed water and the control groups in a similar manner, there seemed to be little reason to suspect such a bias in the results, based on the above comparisons.

In 1983, when the results of the 1980 U.S. Census (VII-25) became available, an additional evaluation was performed to compare some characteristics of the surveyed women with those of women who resided in the same census tracts one year earlier during April, 1980, at the time of the Census. Of the 2,523 adult women in the household survey, 2,519 stated their age, thus allowing a comparison with the Census population for the same geographic area. As shown in Figure VII-12 the target population identified by the U.S. Census was similar in age structure to the population included in the environmental health survey with two

AGE DISTRIBUTION OF TARGET POPULATION, 1980 AND ENVIRONMENTAL HEALTH SURVEY, 1981

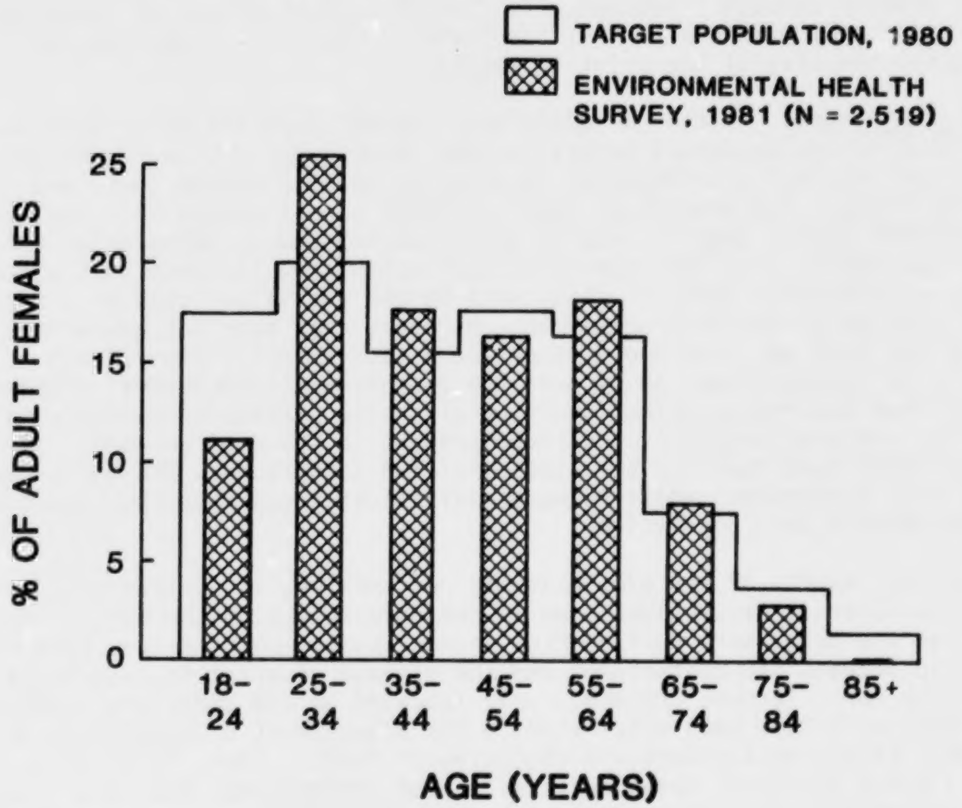


FIGURE VII-12 AGE DISTRIBUTION OF TARGET POPULATION, 1980 AND ENVIRONMENTAL HEALTH SURVEY, 1981

exceptions. First, women aged 18-24 years were underrepresented in the survey and second, women aged 25-34 years were overrepresented. In general, it could be expected that 25-34 year olds would be a more stable, and consequently available, group for surveying than would younger women. With respect to the health conditions included in the environmental health survey, it is doubtful that this lack of representativeness in the younger ages would have a noticeable effect on the results. Since age was controlled for in the analysis, any comparison of the high reclaimed water area with the central control area would adjust for potential differences in the age composition of the two populations.

In summary, the survey responses of more than 2,500 women provided further evidence that the consumption of reclaimed water had not been associated with a measurable increase in the rate of disease. This did not mean that there were no harmful agents in the reclaimed water or that potential contaminants did not cause any adverse effects. Instead, the results indicated that if reclaimed water had adversely affected health, the level of that effect was too small to detect, given the size of the existing sample.

Simulation Model. To provide additional insight into the results of the ecologic studies and household survey, a simulation model was developed to determine the theoretical effects of exposure to various contaminants and disease incidence. The simulation model differed significantly from the basic risk assessment models used to develop water quality and drinking water standards. These models have been concerned with estimating the dose that would result in an acceptable level of risk, such as one additional case of a disease over the lifetime of one million people. However, they have not addressed whether or not that one case would represent a statistically significant increase in an epidemiologic study over the background (no-exposure) disease levels, or what the health effect would be given the particular epidemiologic, demographic, and environmental conditions present in the exposed area. The simulation model developed for the study included such factors and built upon the basic risk assessment models to more realistically estimate the impact of an actual contaminant on a population.

To put the results of the simulation in perspective, it is important to note the three fundamental assumptions used in the development of the model. First, the data for the model were derived from animal studies which assume that the relationship between the contaminant and the disease observed in animals is applicable to man. Second, the model only focussed on the additional risk of disease that could have been attributed to the presence of a contaminant in the water supply (i.e., no exposure via ingestion of food). Thus, if drinking water was only a minor source of human exposure to the contaminant, the total impact of that contaminant from all sources might have been much greater than the model suggested. While water might not be the primary source of exposure, it might be the medium most amenable to control and therefore would represent an important factor for disease prevention to the community. Third, the model dealt with an exposure to a single compound. This could have resulted in either an underestimation or overestimation of the total amount of illness associated with the consumption of a water supply with more than one contaminant. The simulation was limited to exposure to a single compound because interactive effects among the substances present in the water supply could not be determined. In the absence of animal toxicology studies of exposure to multiple components, any evaluation of antagonistic, additive, or synergistic effects in humans must be based on purely hypothetical grounds. Though the model was not able to address those effects directly, some crude and indirect procedures to deal with the possibility were presented. These included using the one-hit low-dose risk assessment extrapolation technique to yield the highest estimates of risk resulting from an exposure (relative to other commonly used risk models), and using cancer at all sites as an outcome measure to account for a broader spectrum of disease than animal testing would suggest.

The results of the simulation study suggested that the model could be a useful tool for understanding environmental conditions that must be present to detect an adverse health outcome in an exposed community. In general, the results suggested that in the face of exposure to a highly toxic waterborne contaminant, a statistically significant increase in the rate of cancer could not be detected in the reclaimed water community, even up to 24 years following exposure. This did not mean that the exposure did not increase the disease rate in the population; the nature of the one-hit extrapolation model used for risk assessment was such that some additional risk results from any exposure level regardless how small. Nor did the findings mean that if the population were followed for more than 24 years a significant increase would not appear. Indeed, the longer the population is exposed, the greater the disease rates due to exposure will be among long-term residents of the area; hence, a significant increase might eventually be detected. This would be especially true for a disease outcome, such as cancer, having the highest risk among older people. Here, even after 24 years of exposure, the older age groups were exposed to the contaminant for a relatively short period of their life and were therefore assigned a small additional risk of disease relative to a cohort of older people who had been exposed since birth. Thus, it could be assumed that the longer the follow-up, the greater the number of individuals with long-term exposure and the greater the level of disease in the continuously exposed community.

As with any model that relies heavily on theoretical precepts, the strong possiblity existed that theory and reality were not synonymous. Several key aspects of the simulation model have already been alluded to in this regard, the major three being extrapolation from animal studies, the low-dose linear risk assessment procedures, and the possibility of interactions among contaminants. Disease rates developed under assumptions concerning these issues might be too high or too low. However, when incorporated with other phases of the epidemiologic data, the model did provide additional understanding of the environmental conditions that must be present to detect an adverse health outcome in an exposed community.

CONCLUSIONS

Does indirect potable water reuse by groundwater recharge cause disease? The epidemiologic evidence presented in this report suggests that at least through 1980 in the Montebello Forebay region of Los Angeles County the answer is "no". To arrive at this conclusion, two types of epidemiologic studies were conducted, an ecologic study and a cross-sectional survey. In addition, the disease experience of the study population was simulated using a computer model.

Ecologic studies using existing vital statistics data are common to epidemiology, providing comprehensive information on the population without having to collect new data. For this study, a wide variety of health outcomes were evaluated including several broad categories of deaths, site-specific categories of cancer deaths, adverse reproductive outcomes, and cases of communicable disease found on occasion to have been transmitted by water. Two populations were compared: those receiving some reclaimed water in their domestic supply since 1962 and those receiving no reclaimed water in their water supply. The population receiving reclaimed water was further divided into groups with high and low exposure.

In ecologic studies, no consideration is given to quantifying exposure at the individual level. Instead the assumption is made that everyone in the "exposed" area has the same contact with the factor of interest, an assumption that may not necessarily be valid, such as in the case of exposure to reclaimed water. "Exposure" also implies that there exists some disease-causing agent in a drinking water source and that the population consumes water containing the agent. Although water quality characterizations have been conducted as part of the overall Study (see Chapters III and IV), there is no way of retrospectively determining whether harmful substances were present in the water supplies of the study population at the time the vital statistics data were collected. Even if no contaminants had been isolated, it does not mean that there were no potentially harmful substances present. Contaminants may well have been overlooked because they were present at such low concentrations and/or because appropriate techniques for isolation and identification may not have been developed. Another problem is that, if present, contaminants may act in some unknown synergistic manner which could contribute to adverse health outcomes. By considering a wide variety of disease outcomes, the ecologic study attempted to address the issue of whether or not previously unidentified agents may have had detectable harmful effects on the consuming public.

The second aspect of exposure, the actual consumption of tap water, could not be addressed in the ecologic study. To determine this information, a cross-sectional survey was conducted of women in the study area. Not only did the survey allow for comparisons of women who consumed reclaimed water to those who did not, it also allowed for control at the individual level for the confounding effects of smoking behavior or alcohol consumption. Results of the survey, conducted some 19 years after the recharge practice first started, indicated no adverse levels of either general or specific health measures that could be attributed to the consumption of reclaimed water.

While the results suggest that there have been no dramatic changes in disease patterns due to water reuse, it cannot be said that potable reuse has had no effect. Rather, it can only be said that the study design and the power of the statistical test were such that no significant difference was detected. To further determine if the sample size was adequate to identify an effect if it actually occurred, a computer model of the study population was developed and tested to determine the effects of various contaminants acting over a 24-year period. The simulation indicated that for certain health outcomes the concentration of known contaminants in the water supply would have to be exceptionally high before any statistically significant increase in disease could be detected.

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TABLE A-1

CHEMICAL AND BACTERIAL WATER QUALITY CHARACTERISTICS OF STUDY SAMPLING SITES (a)

Parameter	Interim Primary Drinking Water Standard (b)	Secondary Drinking Water Standard (c)	LACSD San Jose Creek WRP Cl_2/$DeCl_2$ 3°			LACSD San Jose Creek WRP Cl_2 2°		LACSD San Jose Creek WRP $UnCl_2$ 2°	
			#5 2/22/79	#18 7/25/79	#59 6/17/80	#2 2/05/79	#20 8/02/79	#1 2/05/79	#19 8/02/79
Turbidity, NTU	0.5-5(d)	5	1.3	1.3	0.09	3.4	1.6	3.4	1.0
Color, CU	-	15	30	25	30	35	25	40	35
pH	-	-	7.46	7.21	7.50	7.73	7.96	7.43	7.69
Dissolved Solids, mg/L	-	500-1500(e)	565	634	662	642	615	627	565
Total Alkalinity, mg/L $CaCO_3$	-	-	234	242	226	298	278	299	278
Chloride, mg/L Cl	-	250-600(f)	114	353	136	148	146	142	111
Sulfate, mg/L SO_4	-	250-600(g)	110	98	136	103	96	104	91
Nitrate, mg/L N	10.0	-	0.13	0.03	0.47	0.05	0.01	0.05	0.01
Nitrite, mg/L N	-	-	0.161	0.035	0.920	0.139	0.012	0.141	0.012
Ammonia, mg/L N	-	-	13.1	13.9	10.5	23.8	15.9	23.5	14.7
Phosphate, mg/L PO_4	-	-	10.2	4.7	6.8	13.7	2.5	14.5	2.6
Fluoride, mg/L F	1.4-2.4(h)		0.37	0.89	0.43	0.57	0.70	0.55	0.58
Cyanide, mg/L CN	-	-	0.015	<0.010	0.020	<0.010	0.020	0.010	0.010
Total Hardness, mg/L $CaCO_3$	-	-	194	216	208	230	217	228	216
Arsenic, mg/L As	0.05	-	0.003	0.004	0.004	0.002	0.006	0.002	0.003
Barium, mg/L Ba	1.0	-	0.42	0.12	0.15	0.22	0.18	0.23	0.25
Cadmium, mg/L Cd	0.01		0.003	<0.003	<0.001	0.001	0.003	0.001	0.003
Chromium, mg/L Cr	0.05	-	<0.001	0.015	0.001	<0.001	0.015	<0.001	0.008
Copper, mg/L Cu	-	1.0	0.011	0.005	0.005	0.005	0.014	0.008	0.008
Iron, mg/L Fe	-	0.3	0.08	0.07	0.10	0.08	0.04	0.15	0.05
Lead, mg/L Pb	0.05	-	0.03	0.02	0.02	0.02	0.03	0.02	0.03
Manganese, mg/L Mn	-	0.05	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Mercury, mg/L Hg	0.002	-	<0.0001	<0.0001	<0.0001	0.0001	<0.0001	0.0001	0.0001
Nickel, mg/L Ni	-	-	0.02	0.02	0.03	0.02	0.03	0.02	0.03
Selenium, mg/L Se	0.01	-	0.001	0.003	0.005	0.002	0.004	0.003	0.004
Silver, mg/L Ag	0.05	-	0.001	0.002	0.001	<0.001	<0.001	<0.001	<0.001
Sodium, mg/L Na	-	-	99	122	148	133	136	129	119
Zinc, mg/L Zn	-	5.0	0.041	0.025	0.050	0.023	0.038	0.026	0.036
TOC, mg/L C	-	-	12.0	9.5	12.5	16.7	13.5	15.2	11.5
Bromide, mg/L Br	-	-	0.33	<0.01	0.26	0.43	0.20	0.48	0.16
Total Coliform, MPN/100 mL	-	-	11	7	23	13	<2	>2.4X10^4	1.3X10^6
Fecal Coliform, MPN/100 mL	-	-	<2	<2	2	2	<2	>2.4X10^4	-
Fecal Strep, MPN/100 mL	-	-	<2	<2	<2	<2	<2	>240	<2
Total Plate Count/mL	-	-	82	260	27	36	175	2.3X10^4	5.6X10^4

Footnotes - see page A-16.

TABLE A-2

CHEMICAL AND BACTERIAL WATER QUALITY CHARACTERISTICS OF STUDY SAMPLING SITES (a)

Parameter	Interim Primary Drinking Water Standard(b)	Secondary Drinking Water Standard (c)	LACSD Pomona WRP $Cl_2/2beCl_2$ 3°		LACSD Whittier Narrows WRP $Cl_2/DeCl_2$ 3°			LACSD Whittier Narrows WRP Cl_2 2°	LACSD Whittier Narrows WRP $UnCl_2$ 2°
			#9 3/08/79	#31 11/08/79	#7 3/02/79	#28 10/25/79	#68 10/06/80	#4 2/13/79	#3 2/13/79
Turbidity, NTU	0.5-5(d)	5	1.2	0.5	0.6	0.5	0.6	1.8	1.4
Color, CU	-	15	20	<5	30	25	15	25	35
pH	-	-	7.20	7.30	7.22	7.23	6.75	7.50	7.43
Dissolved Solids, mg/L	-	500-1500(e)	534	510	553	583	502	508	488
Total Alkalinity, mg/L $CaCO_3$	-	-	210	215	229	240	166	251	252
Chloride, mg/L Cl	-	250-600(f)	86	101	99	83	92	93	81
Sulfate, mg/L SO_4	-	250-600(g)	109	111	131	113	98	108	112
Nitrate, mg/L N	10.0	-	0.021	0.020	0.188	0.330	1.50	0.320	0.510
Nitrite, mg/L N	-	-	0.100	0.012	0.241	0.881	0.844	1.410	1.340
Ammonia, mg/L N	-	-	11.1	12.8	21.7	14.5	11.9	22.5	23.2
Phosphate, mg/L PO_4	-	-	20.3	13.1	8.7	6.3	14.8	4.5	4.6
Fluoride, mg/L F	1.4-2.4(h)	-	0.75	0.64	0.87	0.76	0.52	0.70	0.68
Cyanide, mg/L CN	-	-	0.01	<0.01	0.01	0.02	<0.01	0.10	0.04
Total Hardness, mg/L $CaCO_3$	-	-	206	210	185	179	150	188	189
Arsenic, mg/L As	0.05	-	0.002	0.006	0.003	0.002	0.003	0.003	0.003
Barium, mg/L Ba	1.0	-	0.14	0.24	0.25	0.32	0.08	0.20	0.20
Cadmium, mg/L Cd	0.01	-	0.001	0.002	0.005	0.002	<0.001	0.007	0.008
Chromium, mg/L Cr	0.005	-	0.02	0.02	0.01	0.01	<0.001	0.01	0.01
Copper, mg/L Cu	-	1.0	0.014	0.01	0.01	0.008	0.005	0.03	0.03
Iron, mg/L Fe	-	0.3	0.03	0.04	0.04	0.08	<0.01	0.08	0.06
Lead, mg/L Pb	0.05	-	0.01	0.03	0.01	0.02	<0.01	0.02	0.03
Manganese, mg/L Mn	-	0.05	0.01	0.01	0.01	0.01	<0.01	0.01	0.01
Mercury, mg/L Hg	0.002	-	<0.0001	0.0002	<0.0001	<0.0001	<0.0001	0.0001	0.0001
Nickel, mg/L Ni	-	-	0.11	0.08	0.01	0.08	0.02	0.16	0.16
Selenium, mg/L Se	0.01	-	0.002	<0.001	0.001	0.007	0.001	0.003	0.003
Silver, mg/L Ag	0.05	-	0.001	0.002	0.001	0.001	0.001	<0.001	<0.001
Sodium, mg/L Na	-	-	95	101	105	97	76	108	99
Zinc, mg/L Zn	-	5.0	0.020	0.042	0.042	0.025	0.021	0.090	0.100
TOC, mg/L C	-	-	11.6	5.0	11.6	18.9	8.2	12.0	11.0
Bromide, mg/L Br	-	-	0.23	0.95	0.28	0.15	0.14	0.32	0.30
Total Coliform, MPN/100 mL	-	-	2	5	2	2	14	8	1.7×10^5
Fecal Coliform, MPN/100 mL	-	-	<2	5	<2	<2	2	2	3.3×10^4
Fecal Strep, MPN/100 mL	-	-	<2	<2	<2	<2	2	<2	2.4×10^3
Total Plate Count/mL	-	-	65	430	170	330	186	39	7.5×10^3

Footnotes - see page A-16.

TABLE A-3

CHEMICAL AND BACTERIAL WATER QUALITY CHARACTERISTICS OF STUDY SAMPLING SITES (a)

Parameter	Interim Primary Drinking Water Standard(b)	Secondary Water Standard (c)	Montebello Forebay Storm Water					
			#40 1/28/79	#80 12/4/81	#87 1/23/81	#88 1/28/81	#89 2/9/81	#90 2/26/81
Turbidity, NTU	0.5-5(d)	5	165	38.5	32.0	143.0	57.0	40.0
Color, CU	-	15	3200	180	160	300	200	150
pH	-	-	7.83	7.81	7.30	7.87	7.70	7.59
Dissolved Solids, mg/L	-	500-1500(e)	135	198	298	112	110	220
Total Alkalinity, mg/L $CaCO_3$	-	-	46	73	85	47	40	61
Chloride, mg/L Cl	-	250-600(f)	10	18	38	12	10	25
Sulfate, mg/L SO_4	-	250-600(g)	31	44	83	28	29	62
Nitrate, mg/l N	10.0	-	0.92	3.37	2.47	0.73	1.22	1.95
Nitrite, mg/L N	-	-	0.101	0.194	0.213	0.074	0.125	0.140
Ammonia, mg/L N	-	-	0.8	1.4	1.7	1.4	0.7	1.7
Phosphate, mg/L PO_4	-	-	2.50	2.48	2.07	3.28	2.31	2.0
Fluoride, mg/L F	1.4-2.4(h)	-	0.22	0.36	0.20	0.20	0.20	0.22
Cyanide, mg/L CN	-	-	0.01	0.02	0.02	0.01	0.02	0.02
Total Hardness, mg/L $CaCO_3$	-	-	67	110	148	80	82	114
Arsenic, mg/L As	0.05	-	0.047	0.0007	0.006	0.003	0.0015	0.004
Barium, mg/L Ba	1.0	-	0.41	0.19	0.14	0.36	0.29	0.15
Cadmium, mg/L Cd	0.01	-	0.002	0.001	0.001	0.003	0.002	0.004
Chromium, mg/L Cr	0.05	-	0.030	0.011	0.008	0.025	0.017	0.009
Copper, mg/L Cu	-	1.0	0.028	0.035	0.015	0.036	0.15	0.015
Iron, mg/L Fe	-	0.3	19.00	4.28	4.22	14.2	9.52	3.55
Lead, mg/L Pb	0.05	-	0.12	0.12	0.01	0.18	0.07	0.04
Manganese, mg/L Mn	-	0.05	0.250	0.19	0.132	0.295	0.12	0.095
Mercury, mg/L Hg	0.002	-	<0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.0001
Nickel, mg/L Ni	-	-	0.030	0.02	0.02	0.02	0.02	0.02
Selenium, mg/L Se	0.01	-	0.004	<0.0005	0.0007	0.0014	-	0.008
Silver, mg/L Ag	0.05	-	0.001	0.001	<0.001	<0.001	<0.001	0.002
Sodium, mg/L Na	-	-	10	16.9	39	12	12	24
Zinc, mg/L Zn	-	5.0	0.102	0.162	0.078	0.110	0.071	0.07
TOC, mg/L C	-	-	17.5	12.4	18.7	18.4	12.6	18.6
Bromide, mg/L Br	-	-	0.11	0.17	0.20	0.10	0.08	0.15
Total Coliform, MPN/100 mL	-	-	$7.9X10^4$	$7.9X10^4$	$1.1X10^5$	$>2.4X10^4$	$3.5x10^2$	$7.9X10^4$
Fecal Coliform, MPN/100 mL	-	-	$8.0X10^3$	$1.3X10^4$	$1.8X10^2$	$>2.4X10^4$	$2.8x10^2$	$7.0X10^3$
Fecal Strep, MPN/100 mL	-	-	$3.5X10^4$	$3.5X10^4$	$5.4X10^5$	$5.4X10^4$	$3.5x10^2$	$7.0X10^3$
Total Plate Count/mL	-	-	$8.8X10^3$	$1.7X10^5$	$3.2X10^4$	$5.5X10^4$	$1.49X10^5$	$5.0X10^4$

Footnotes - see Page A-16.

TABLE A-4

CHEMICAL AND BACTERIAL WATER QUALITY CHARACTERISTICS OF STUDY SAMPLING SITES (a)

Parameter	Interim Primary Drinking Water Standard(b)	Secondary Water Standard (c)	MWD Colorado River Water			MWD State Project Water		
			#32 11/15/79	#43 2/14/80	#86 1/13/81	#33 11/20/79	#42 2/07/80	#85 1/08/81
Turbidity, NTU	0.5-5(d)	5	2.9	2.5	0.40	1.3	5.5	0.30
Color, CU	-	15	<5	5	5	15	30	20
pH	-	-	8.00	8.00	8.00	8.12	8.02	8.06
Dissolved Solids, mg/L	-	500-1500(e)	587	685	720	350	477	190
Total Alkalinity, mg/L $CaCO_3$	-	-	125	127	128	84	68	65
Chloride, mg/L Cl	-	250-600(f)	95	94	100	93	49	40
Sulfate, mg/L SO_4	-	250-600(g)	321	304	300	34	35	33
Nitrate, mg/l N	10.0	-	0.26	0.14	0.08	0.33	0.92	0.56
Nitrite, mg/L N	-	-	0.001	<0.001	<0.001	<0.001	0.009	<0.001
Ammonia, mg/L N	-	-	0.2	<0.1	<0.1	0.1	<0.1	<0.1
Phosphate, mg/L PO_4	-	-	0.07	0.10	0.06	0.35	0.29	0.24
Fluoride, mg/L F	1.4-2.4(h)	-	0.37	0.38	0.36	0.12	<0.10	0.16
Cyanide, mg/L CN	-	-	<0.01	<0.01	0.01	<0.01	<0.01	0.01
Total Hardness, mg/L $CaCO_3$	-	-	332	333	337	106	90	82
Arsenic, mg/L As	0.05	-	0.007	0.002	0.001	0.002	0.003	0.001
Barium, mg/L Ba	1.0	-	0.83	0.30	0.24	0.26	0.15	0.07
Cadmium, mg/L Cd	0.01	-	0.003	0.002	0.002	<0.001	0.002	0.001
Chromium, mg/L Cr	0.05	-	0.001	0.001	0.002	0.002	0.001	0.003
Copper, mg/L Cu	-	1.0	<0.005	0.005	0.008	<0.005	<0.005	0.020
Iron, mg/L Fe	-	0.3	0.20	0.16	0.19	0.10	0.43	0.12
Lead, mg/L Pb	0.05	-	0.01	0.02	<0.01	0.02	0.02	<0.01
Manganese, mg/L Mn	-	0.05	0.016	0.010	0.01	0.010	0.015	0.005
Mercury, mg/L Hg	0.002	-	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nickel, mg/L Ni	-	-	0.010	0.005	0.008	0.010	0.005	0.02
Selenium, mg/L Se	0.01	-	<0.001	0.003	<0.005	<0.001	0.003	<0.0005
Silver, mg/L Ag	0.05	-	<0.001	0.002	0.001	<0.001	<0.001	0.001
Sodium, mg/L Na	-	-	58	111	103	64	38	33
Zinc, mg/L Zn	-	5.0	0.006	0.003	<0.005	0.020	0.004	0.120
TOC, mg/L C	-	-	3.1	3.0	3.50	3.1	6.3	3.43
Bromide, mg/L Br	-	-	0.02	0.27	0.04	0.40	0.13	0.12
Total Coliform, MPN/100 mL	-	-	<2	<2	<2	3	33	5
Fecal Coliform, MPN/100 mL	-	-	<2	<2	<2	3	-	<2
Fecal Strep, MPN/100 mL	-	-	<2	<2	<2	<2	5	2
Total Plate Count/mL	-	-	<0.5	0.3	2	30.5	74.0	42

Footnotes - see page A-16.

TABLE A-5

CHEMICAL AND BACTERIAL WATER QUALITY CHARACTERISTICS OF STUDY SAMPLING SITES (a)

Parameter	Interim Primary Drinking Water Standard(b)	Secondary Drinking Water Standard (c)	City of Montebello Well 2907 Cl_2			Park Water Co. Well 1562E $UnCl_2$		
			#10 3/13/79	#39 1/23/80	#51 4/03/80	#41 1/31/80	#47 3/10/80	#58 5/05/80
Turbidity, NTU	0.5-5(d)	5	0.0	0.2	1.4	6.0	14.0	1.0
Color, CU	-	15	<5	5	<5	15	35	<5
pH	-	-	7.61	7.56	7.35	7.91	8.04	7.90
Dissolved Solids, mg/L	-	500-1500(e)	202	647	626	527	478	527
Total Alkalinity, mg/L $CaCO_3$	-	-	179	185	204	157	164	140
Chloride, mg/L Cl	-	250-600(f)	100	111	104	67	71	66
Sulfate, mg/L SO_4	-	250-600(g)	181	176	180	174	182	170
Nitrate, mg/L N	10.0	-	0.82	0.51	0.38	0.08	0.10	0.08
Nitrite, mg/L N	-	-	0.002	0.002	0.003	0.018	0.012	0.011
Ammonia, mg/L N	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	0.1
Phosphate, mg/L PO_4	-	-	0.12	0.10	0.03	1.00	1.42	0.37
Fluoride, mg/L F	1.4-2.4(h)	-	0.51	0.52	0.51	0.34	0.32	0.39
Cyanide, mg/L CN	-	-	<0.01	<0.01	<0.01	<0.01	0.01	<0.01
Total Hardness, mg/L $CaCO_3$	-	-	269	298	269	276	276	270
Arsenic, mg/L As	0.05	-	0.001	0.009	0.003	0.008	0.015	0.004
Barium, mg/L Ba	1.0	-	0.38	0.28	0.32	0.42	0.33	0.26
Cadmium, mg/L Cd	0.01	-	0.002	0.002	0.003	0.001	0.003	0.003
Chromium, mg/L Cr	0.05	-	0.001	<0.001	<0.001	<0.001	<0.001	0.001
Copper, mg/L Cu	-	1.0	0.005	<0.005	0.008	0.005	0.015	0.015
Iron, mg/L Fe	-	0.3	0.10	0.05	0.06	0.98	4.06	0.28
Lead, mg/L Pb	0.05	-	<0.01	0.03	0.03	0.03	0.01	0.03
Manganese, mg/L Mn	-	0.05	0.015	0.020	0.020	0.280	0.310	0.29
Mercury, mg/L Hg	0.002	-	0.0005	0.0004	0.0002	0.0001	0.0001	<0.0001
Nickel, mg/L Ni	-	-	0.01	0.01	0.01	0.008	0.010	0.01
Selenium, mg/L Se	0.01	-	0.002	0.006	0.002	0.006	<0.001	0.004
Silver, mg/L Ag	0.05	-	0.002	0.002	0.001	<0.001	0.001	0.003
Sodium, mg/L Na	-	-	110	114	102	69	55	69
Zinc, mg/L Zn	-	5.0	0.138	0.170	0.120	0.070	0.088	0.020
TOC, mg/L C	-	-	1.3	3.9	1.4	1.06	0.77	0.58
Bromide, mg/L Br	-	-	0.44	0.41	0.29	0.30	0.16	0.18
Total Coliform, MPN/100 mL	-	-	<2	<2	-	<2	<2	<2
Fecal Coliform, MPN/100 mL	-	-	<2	<2	-	<2	<2	<2
Fecal Strep, MPN/100 mL	-	-	<2	<2	-	2	<2	2
Total Plate Count/mL	-	-	2.0	<0.5	-	5.3	<0.5	205

Footnotes - see page A-16.

TABLE A-6

CHEMICAL AND BACTERIAL WATER QUALITY CHARACTERISTICS OF STUDY SAMPLING SITES (a)

Parameter	Interim Primary Drinking Water Standard(b)	Secondary Drinking Water Standard (c)	La Habra Heights MWC Well 1621 MM $UnCl_2$			City of Southgate Well 1514A $UnCl_2$		
			#17 4/24/79	#45 3/03/80	#53 4/10/80	#16 4/19/79	#44 2/25/80	#55 4/21/80
Turbidity, NTU	0.5-5(d)	5	1.4	0.8	2.2	<0.1	0.4	0.2
Color, CU	-	15	<5	5	5	<5	5	<5
pH	-	-	7.74	7.52	7.46	7.74	7.72	7.97
Dissolved Solids, mg/L	-	500-1500(e)	486	472	464	466	481	488
Total Alkalinity, mg/L $CaCO_3$	-	-	169	161	162	207	196	201
Chloride, mg/L Cl	-	250-600(f)	66	66	120	51	35	50
Sulfate, mg/L SO_4	-	250-600(g)	117	117	120	121	129	120
Nitrate, mg/L N	10.0	-	3.47	3.28	3.28	0.20	2.17	2.17
Nitrite, mg/L N	-	-	<0.001	<0.001	0.002	0.008	<0.001	0.002
Ammonia, mg/L N	-	-	0.29	<0.10	<0.10	0.30	<0.10	0.20
Phosphate, mg/L PO_4	-	-	0.11	0.24	1.54	0.14	0.20	0.13
Fluoride, mg/L F	1.4-2.4(h)	-	0.54	0.46	0.43	0.42	0.39	0.39
Cyanide, mg/L CN	-	-	<0.01	<0.01	0.01	<0.01	<0.01	<0.01
Total Hardness, mg/L $CaCO_3$	-	-	234	241	237	308	305	315
Arsenic, mg/L As	0.05	-	0.003	0.005	0.002	0.003	0.002	0.004
Barium, mg/L Ba	1.0	-	0.34	0.22	0.23	0.24	0.34	0.29
Cadmium, mg/L Cd	0.01	-	0.001	0.002	0.003	0.002	0.002	0.002
Chromium, mg/L Cr	0.05	-	0.001	0.012	0.003	0.001	0.002	0.002
Copper, mg/L Cu	-	1.0	<0.005	<0.005	0.005	<0.005	<0.005	<0.005
Iron, mg/L Fe	-	0.3	1.02	0.01	0.54	0.01	0.01	0.02
Lead, mg/L Pb	0.05	-	0.01	0.02	0.02	<0.01	0.03	0.01
Manganese, mg/L Mn	-	0.05	0.011	0.005	0.008	<0.005	0.140	0.005
Mercury, mg/L Hg	0.002	-	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nickel, mg/L Ni	-	-	0.010	0.010	0.005	0.008	0.250	<0.005
Selenium, mg/L Se	0.01	-	0.001	0.001	0.001	0.004	0.002	0.001
Silver, mg/L Ag	0.05	-	0.001	<0.001	0.002	<0.001	<0.001	0.002
Sodium, mg/L Na	-	-	69	65	65	39	38	42
Zinc, mg/L Zn	-	5.0	0.010	0.001	0.008	0.002	0.002	0.004
TOC, mg/L C	-	-	0.66	0.68	0.84	0.61	0.63	0.47
Bromide, mg/L Br	-	-	0.18	0.18	0.36	0.16	0.20	0.17
Total Coliform, MPN/100 mL	-	-	5	<2	<2	<2	<2	<2
Fecal Coliform, MPN/100 mL	-	-	<2	<2	<2	<2	<2	<2
Fecal Strep, MPN/100 mL	-	-	<2	<2	<2	<2	<2	<2
Total Plate Count/mL	-	-	0.5	0.5	0.5	<0.5	0.5	3.5

Footnotes - see page A-16.

TABLE A-7

CHEMICAL AND BACTERIAL WATER QUALITY CHARACTERISTICS OF STUDY SAMPLING SITES (a)

Parameter	Interim Primary Drinking Water Standard(b)	Secondary Drinking Water Standard (c)	S. Montebello Irrigation District Well 1580J $UnCl_2$			City of Downey Well 1566A $UnCl_2$		
			#6 2/26/79	#34 11/27/79	#49 3/17/80	#8 3/5/79	#35 11/29/79	#50 3/31/80
Turbidity, NTU	0.5-5(d)	5	<0.1	0.2	0.4	0.0	0.1	1.4
Color, CU	-	15	<5	5	<5	<5	5	5
pH	-	-	7.60	7.53	7.65	7.52	7.67	7.67
Dissolved Solids, mg/L	-	500-1500(e)	352	546	332	574	521	548
Total Alkalinity, mg/L $CaCO_3$	-	-	131	134	129	178	182	217
Chloride, mg/L Cl	-	250-600(f)	36	40	46	66	66	66
Sulfate, mg/L SO_4	-	250-600(g)	88	76	67	165	167	165
Nitrate, mg/l N	10.0	-	3.45	2.52	2.75	2.36	2.48	2.54
Nitrite, mg/L N	-	-	<0.001	<0.001	<0.001	<0.001	0.003	<0.001
Ammonia, mg/L N	-	-	<0.1	0.1	0.2	<0.1	<0.1	<0.1
Phosphate, mg/L PO_4	-	-	1.80	0.01	0.08	0.06	0.05	0.08
Fluoride, mg/L F	1.4-2.4(h)	-	0.42	0.39	0.48	0.46	0.42	0.40
Cyanide, mg/L CN	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total Hardness, mg/L $CaCO_3$	-	-	148	144	140	356	355	347
Arsenic, mg/L As	0.05	-	0.002	0.002	0.002	0.002	0.005	0.002
Barium, mg/L Ba	1.0	-	0.22	0.09	0.12	0.38	0.34	0.42
Cadmium, mg/L Cd	0.01	-	<0.001	0.002	0.002	0.002	0.002	0.001
Chromium, mg/L Cr	0.05	-	0.003	0.001	0.006	0.002	0.008	<0.001
Copper, mg/L Cu	-	1.0	0.008	<0.005	<0.005	<0.005	0.005	0.007
Iron, mg/L Fe	-	0.3	<0.01	0.03	0.02	0.01	0.02	0.01
Lead, mg/L Pb	0.05	-	0.02	<0.01	0.03	0.01	0.02	0.01
Manganese, mg/L Mn	-	0.05	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Mercury, mg/L Hg	0.002	-	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0001
Nickel, mg/L Ni	-	-	0.010	0.008	0.010	0.010	0.010	<0.005
Selenium, mg/L Se	0.01	-	0.001	<0.001	0.002	0.001	0.009	0.001
Silver, mg/L Ag	0.05	-	0.002	0.001	0.001	0.001	0.001	<0.001
Sodium, mg/L Na	-	-	58	60	56	40	42	-
Zinc, mg/L Zn	-	5.0	0.006	0.002	0.003	0.008	0.004	0.003
TOC, mg/L C	-	-	0.76	0.67	5.12	0.55	0.41	0.56
Bromide, mg/L Br	-	-	0.23	0.18	0.25	0.27	0.14	0.10
Total Coliform, MPN/100 mL	-	-	<2	<2	<2	<2	<2	<2
Fecal Coliform, MPN/100 mL	-	-	<2	<2	<2	<2	<2	<2
Fecal Strep, MPN/100 mL	-	-	<2	<2	<2	<2	<2	<2
Total Plate Count/mL	-	-	4.0	6.5	3.5	23.0	<0.5	0.5

Footnotes - see page A-16.

TABLE A-8

CHEMICAL AND BACTERIAL WATER QUALITY CHARACTERISTICS OF STUDY SAMPLING SITES (a)

Parameter	Interim Primary Drinking Water Standard(b)	Secondary Drinking Water Standard (c)	San Gabriel Valley Water Company Well 1620GG UnCl$_2$			Byrd Well 2958A Cl$_2$		
			#23 8/30/79	#46 3/06/80	#57 5/01/80	#12 3/21/79	#21 8/20/79	#56 4/28/80
Turbidity, NTU	0.5-5(d)	5	0.6	0.4	0.1	0.0	0.4	0.4
Color, CU	-	15	<5	5	<5	<5	<5	<5
pH	-	-	7.59	7.70	7.47	7.29	7.30	7.49
Dissolved Solids, mg/L	-	500-1500(e)	528	398	470	723	700	716
Total Alkalinity, mg/L CaCO$_3$	-	-	187	188	179	269	251	255
Chloride, mg/L Cl	-	250-600(f)	63	92	66	69	67	66
Sulfate, mg/L SO$_4$	-	250-600(g)	123	126	120	214	185	200
Nitrate, mg/L N	10.0	-	3.03	3.11	3.26	3.73	3.30	4.02
Nitrite, mg/L N	-	-	0.004	0.001	<0.001	0.006	0.001	<0.001
Ammonia, mg/L N	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Phosphate, mg/L PO$_4$	-	-	0.17	0.17	0.26	0.02	1.90	0.31
Fluoride, mg/L F	1.4-2.4(h)	-	0.34	0.61	0.34	0.14	0.38	0.17
Cyanide, mg/L CN	-	-	0.01	<0.01	<0.01	<0.01	0.03	<0.01
Total Hardness, mg/L CaCO$_3$	-	-	255	299	247	461	437	436
Arsenic, mg/L As	0.05	-	0.005	0.002	0.004	0.002	0.003	0.002
Barium, mg/L Ba	1.0	-	0.58	0.24	0.22	0.42	0.88	0.32
Cadmium, mg/L Cd	0.01	-	0.002	0.001	0.003	0.003	0.003	0.004
Chromium, mg/L Cr	0.05	-	0.005	<0.001	<0.001	0.002	0.001	0.003
Copper, mg/L Cu	-	1.0	0.010	<0.005	<0.005	0.005	0.031	0.005
Iron, mg/L Fe	-	0.3	0.02	0.01	0.06	0.03	0.02	<0.01
Lead, mg/L Pb	0.05	-	0.02	0.02	0.03	0.02	0.03	<0.01
Manganese, mg/L Mn	-	0.05	<0.005	0.005	0.005	<0.005	<0.010	0.005
Mercury, mg/L Hg	0.002	-	<0.0001	<0.0001	<0.0001	<0.0001	0.0002	<0.0001
Nickel, mg/L Ni	-	-	<0.005	<0.005	0.010	0.010	0.030	0.020
Selenium, mg/L Se	0.01	-	<0.001	0.003	0.004	0.002	0.008	0.003
Silver, mg/L Ag	0.05	-	0.001	<0.001	0.004	0.001	0.002	0.002
Sodium, mg/L Na	-	-	68	70	68	49	59	59
Zinc, mg/L Zn	-	5.0	0.010	0.008	0.002	0.005	0.070	0.006
TOC, mg/L C	-	-	1.00	0.88	0.77	0.63	0.88	0.60
Bromide, mg/L Br	-	-	0.22	0.19	0.22	0.23	0.14	-
Total Coliform, MPN/100 mL	-	-	2	<2	<2	<2	<2	<2
Fecal Coliform, MPN/100 mL	-	-	<2	<2	<2	<2	<2	<2
Fecal Strep, MPN/100 mL	-	-	<2	<2	<2	<2	<2	<2
Total Plate Count/mL	-	-	27.5	0.5	<0.5	<0.5	27.5	<0.5

Footnotes - see page A-16.

TABLE A-9

CHEMICAL AND BACTERIAL WATER QUALITY CHARACTERISTICS OF STUDY SAMPLING SITES (a)

Parameter	Interim Primary Drinking Water Standard(b)	Secondary Drinking Water Standard (c)	City of Pico Rivera Well 1591H $UnCl_2$			City of Whittier Well 2947Q $UnCl_2$		
			#11 3/15/79	#22 8/22/79	#52 4/7/80	#15 4/17/79	#48 3/13/80	#54 4/17/80
Turbidity, NTU	0.5-5(d)	5	0.0	0.2	<1	<0.1	0.4	<1
Color, CU	-	15	5	5	<5	<5	5	<5
pH	-	-	7.53	7.53	7.75	7.88	7.87	7.95
Dissolved Solids, mg/L	-	500-1500(e)	398	434	306	306	249	276
Total Alkalinity, mg/L $CaCO_3$	-	-	136	148	156	167	157	159
Chloride, mg/L Cl	-	250-600(f)	43	49	32	24	13	18
Sulfate, mg/L SO_4	-	250-600(g)	110	106	63	58	38	47
Nitrate, mg/l N	10.0	-	1.85	1.68	2.39	0.92	0.70	1.17
Nitrite, mg/L N	-	-	0.006	0.004	0.002	0.010	0.002	0.002
Ammonia, mg/L N	-	-	0.1	0.1	<0.1	0.4	0.1	<0.1
Phosphate, mg/L PO_4	-	-	0.10	2.90	0.92	<0.03	0.24	0.03
Fluoride, mg/L F	1.4-2.4(h)	-	0.41	0.49	0.47	0.38	0.35	0.36
Cyanide, mg/L CN	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
Total Hardness, mg/L $CaCO_3$	-	-	193	210	124	213	170	383
Arsenic, mg/L As	0.05	-	0.002	0.004	0.004	0.002	0.002	0.002
Barium, mg/L Ba	1.0	-	0.18	0.53	0.12	0.26	0.28	0.33
Cadmium, mg/L Cd	0.01	-	<0.001	0.001	<0.001	0.002	0.001	<0.001
Chromium, mg/L Cr	0.05	-	<0.001	0.002	<0.001	0.002	0.004	0.003
Copper, mg/L Cu	-	1.0	0.005	0.014	<0.005	0.005	<0.005	<0.005
Iron, mg/L Fe	-	0.3	0.030	<0.010	0.005	0.030	<0.005	0.005
Lead, mg/L Pb	0.05	-	0.02	0.02	<0.01	0.02	0.02	<0.01
Manganese, mg/L Mn	-	0.05	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Mercury, mg/L Hg	0.002	-	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nickel, mg/L Ni	-	-	0.010	0.010	0.010	0.010	0.005	<0.005
Selenium, mg/L Se	0.01	-	0.003	0.002	<0.001	0.002	<0.001	0.001
Silver, mg/L Ag	0.05	-	0.001	0.002	<0.001	<0.001	0.003	<0.001
Sodium, mg/L Na	-	-	51	55	49	22	17	18
Zinc, mg/L Zn	-	5.0	0.001	0.024	0.005	0.088	0.156	0.013
TOC, mg/L C	-	-	0.75	0.95	1.16	0.31	0.27	0.37
Bromide, mg/L Br	-	-	0.22	0.20	0.16	0.06	0.03	0.05
Total Coliform, MPN/100 mL	-	-	<2	<2	<2	<2	<2	<2
Fecal Coliform, MPN/100 mL	-	-	<2	<2	<2	<2	<2	<2
Fecal Strep, MPN/100 mL	-	-	<2	<2	<2	<2	<2	<2
Total Plate Count/mL	-	-	2.0	18.5	<0.5	1.0	9.0	2.0

Footnotes - see page A-16.

TABLE A-10

CHEMICAL AND BACTERIAL WATER QUALITY CHARACTERISTICS OF STUDY SAMPLING SITES (a)

Parameter	Interim Primary Drinking Standard(b)	Secondary Drinking Water (c)	LA/Glendale WRP Cl_2 3°			Los Angeles River Dry Weather Runoff		
			#14 4/12/79	#71 10/23/80	#84 12/23/80	#37 12/10/79	#69 10/08/80	#83 12/17/80
Turbidity, NTU	0.5-5(d)	5	1.20	1.30	0.15	1.51	1.70	5.7
Color, CU	-	15	25	20	25	70	50	40
pH	-	-	7.13	7.08	7.11	8.22	8.04	8.27
Dissolved Solids, mg/L	-	500-1500(e)	618	483	534	678	820	907
Total Alkalinity, mg/L $CaCO_3$	-	-	182	139	137	225	233	248
Chloride, mg/L Cl	-	250-600(f)	122	95	110	61	78	79
Sulfate, mg/L SO_4	-	250-600(g)	197	120	130	253	302	290
Nitrate, mg/L N	10.0	-	1.21	2.26	4.24	1.45	1.82	2.94
Nitrite, mg/L N	-	-	0.640	0.043	0.201	0.111	0.083	0.040
Ammonia, mg/L N	-	-	11.3	8.1	5.5	<0.1	0.1	0.2
Phosphate, mg/L PO_4	-	-	11.3	6.8	20.4	0.6	0.7	0.26
Fluoride, Mg/L F	1.4-2.4(h)	-	0.74	0.98	0.84	0.56	0.58	0.52
Cyanide, mg/L CN	-	-	0.05	0.20	0.02	0.01	0.01	0.01
Total Hardness, mg/L $CaCO_3$	-	-	203	146	167	399	455	527
Arsenic, mg/L As	0.05	-	0.008	0.006	0.0075	0.006	0.007	0.0058
Barium, mg/L Ba	1.0	-	0.06	0.16	0.08	0.26	0.22	0.18
Cadmium, mg/L Cd	0.01	-	0.033	0.06	0.033	0.002	<0.001	<0.001
Chromium, mg/L Cr	0.05	-	0.050	0.060	0.052	0.002	0.010	0.002
Copper, mg/L Cu	-	1.0	0.120	0.015	0.01	0.012	0.010	0.012
Iron, mg/L Fe	-	0.3	0.10	0.09	0.05	0.23	0.11	0.14
Lead, mg/L Pb	0.05	-	<0.01	<0.01	0.01	0.03	0.01	0.03
Manganese, mg/L Mn	-	0.05	0.020	0.018	0.016	0.040	0.04	0.026
Mercury, mg/L Hg	0.002	-	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nickel, mg/L Ni	-	-	0.26	0.30	0.19	0.02	0.02	0.02
Selenium, mg/L Se	0.01	-	0.003	0.002	0.009	0.002	0.004	0.0102
Silver, mg/L Ag	0.05	-	<0.001	0.002	<0.001	0.001	0.002	0.002
Sodium, mg/L Na	-	-	131	106	120	81	80	90
Zinc, mg/L Zn	-	5.0	0.152	0.132	0.089	0.007	0.007	0.033
TOC, mg/L C	-	-	13.10	9.80	8.34	6.60	8.00	6.18
Bromide, mg/L Br	-	-	0.67	0.91	0.37	0.32	0.38	0.38
Total Coliform, MPN/100 mL	-	-	4	<2	15	7.0×10^3	4.9×10^4	7.9×10^4
Fecal Coliform, MPN/100 mL	-	-	<3	<2	ND	1.1×10^3	9.0×10^3	200
Fecal Strep, MPN/100 mL	-	-	<2	<2	<2	490	1.3×10^3	1.3×10^3
Total Plate Count/mL	-	-	2.1	145	65	3.4×10^3	7.9×10^4	2.0×10^4

Footnotes - see page A-16.

TABLE A-11

CHEMICAL AND BACTERIAL WATER QUALITY CHARACTERISTICS OF STUDY SAMPLING SITES (a)

Parameter	Interim Primary Drinking Standard (b)	Secondary Drinking Water (c)	Hollywood Wells Collector DWP UnCl$_2$			Pollack Wells DWP UnCl$_2$		
			#36 12/06/79	#72(i) 10/29/80	#82 12/15/80	#38 12/13/79	#70 10/15/80	#81 12/11/80
Turbidity, NTU	0.5-5(d)	5	<0.02	0.28	0.4	<0.02	0.24	0.08
Color, CU	-	15	<5	5	<5	5	5	<5
pH	-	-	7.69	7.83	7.79	7.10	8.20	7.29
Dissolved Solids, mg/L	-	500-1500(e)	171	335	343	776	463	767
Total Alkalinity, mg/L $CaCO_3$	-	-	208	210	228	262	191	215
Chloride, mg/L Cl	-	250-600(f)	13	18	15	105	37	100
Sulfate, mg/L SO_4	-	250-600(g)	34	40	37	216	140	240
Nitrate, mg/l N	10.0	-	3.80	4.57	4.10	2.53	2.91	2.22
Nitrite, mg/L N	-	-	0.001	0.003	0.003	0.003	0.008	0.004
Ammonia, mg/L N	-	-	<0.1	0.2	<0.1	<0.1	0.2	<0.1
Phosphate, mg/L PO_4	-	-	0.2	0.1	0.16	0.2	0.4	0.23
Fluoride, mg/L F	1.4-2.4(h)	-	0.36	0.34	0.42	0.31	0.51	0.30
Cyanide, mg/L CN	-	-	0.01	0.01	0.01	<0.01	<0.01	0.03
Total Hardness, mg/L $CaCO_3$	-	-	233	232	252	434	246	438
Arsenic, mg/L As	0.05	-	0.002	<0.001	0.0005	0.003	0.004	0.0018
Barium, mg/L Ba	1.0	-	0.30	0.60	0.30	0.27	0.17	0.19
Cadmium, mg/L Cd	0.01	-	0.002	<0.001	0.001	0.003	<0.001	0.002
Chromium, mg/L Cr	0.05	-	0.002	0.002	0.001	0.002	0.002	<0.001
Copper, mg/L Cu	-	1.0	<0.005	<0.005	<0.005	0.021	0.008	0.022
Iron, mg/L Fe	-	0.3	0.01	<0.01	<0.01	0.05	0.04	0.02
Lead, mg/L Pb	0.05	-	0.01	<0.01	0.02	0.01	0.02	<0.01
Manganese, mg/L Mn	-	0.05	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Mercury, mg/L Hg	0.002	-	<0.0001	<0.0001	0.0001	<0.0001	0.0004	<0.0001
Nickel, mg/L Ni	-	-	0.01	0.005	<0.005	0.01	0.008	<0.005
Selenium, mg/L Se	0.01	-	0.001	0.001	0.0066	0.002	0.002	0.0099
Silver, mg/L Ag	0.05	-	0.002	<0.001	<0.001	<0.001	0.002	0.002
Sodium, mg/L Na	-	-	21	22	23	96	49	90
Zinc, mg/L Zn	-	5.0	0.008	0.001	0.018	0.015	<0.001	0.008
TOC, mg/L C	-	-	0.40	0.41	0.34	1.41	0.39	1.01
Bromide, mg/L Br	-	-	0.07	0.62	0.09	0.52	0.16	0.51
Total Coliform, MPN/100 mL	-	-	<2	<2	<2	<2	<2	<2
Fecal Coliform, MPN/100 mL	-	-	<2	<2	<2	<2	<2	<2
Fecal Strep, MPN/100 mL	-	-	<2	<2	<2	<2	<2	<2
Total Plate Count/mL	-	-	<0.5	7	<0.5	0.5	4	2

Footnotes - see page A-16.

TABLE A-12

CHEMICAL AND BACTERIAL WATER QUALITY CHARACTERISTICS OF STUDY SAMPLING SITES (a)

Parameter	Interim Primary Drinking Standard(b)	Secondary Drinking Water (c)	Yorba Linda Well 11 Cl_2			Anaheim Well 27 $UnCl_2$		
			#24 9/24/79	#60 9/02/80	#73 11/04/80	#25 10/04/79	#61 9/08/80	#74 11/06/80
Turbidity, NTU	0.5-5(d)	5	0.1	1.5	0.06	0.1	0.1	0.02
Color, CU	-	15	<5	<5	5	<5	5	5
pH	-	-	7.80	7.62	7.66	7.70	7.60	7.70
Dissolved Solids, mg/L	-	500-1500(e)	594	645	642	603	615	596
Total Alkalinity, mg/L $CaCO_3$	-	-	225	214	222	216	194	197
Chloride, mg/L Cl	-	250-600(f)	104	102	105	96	94	66
Sulfate, mg/L SO_4	-	250-600(g)	129	130	140	155	170	180
Nitrate, mg/L N	10.0	-	3.22	3.30	3.85	3.54	3.51	3.21
Nitrite, mg/L N	-	-	0.002	<0.001	<0.001	<0.001	<0.001	<0.001
Ammonia, mg/L N	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Phosphate, mg/L PO_4	-	-	0.83	0.8	0.014	0.20	0.05	0.02
Fluoride, mg/L F	1.4-2.4(h)	-	0.63	0.50	0.48	0.42	0.37	0.38
Cyanide, mg/L CN	-	-	<0.01	0.01	0.02	0.02	0.01	<0.01
Total Hardness, mg/L $CaCO_3$	-	-	322	312	336	318	300	311
Arsenic, mg/L As	0.05	-	0.006	0.003	0.0026	0.004	<0.001	0.0006
Barium, mg/L Ba	1.0	-	0.21	0.19	0.24	0.32	0.40	0.20
Cadmium, mg/L Cd	0.01	-	0.004	<0.001	0.001	0.004	0.004	0.003
Chromium, mg/L Cr	0.05	-	0.004	<0.001	0.001	<0.001	<0.001	<0.001
Copper, mg/L Cu	-	1.0	0.038	0.014	0.012	0.006	<0.005	0.012
Iron, mg/L Fe	-	0.3	0.05	0.01	0.05	0.08	0.02	0.01
Lead, mg/L Pb	0.05	-	0.04	<0.01	0.03	0.04	0.03	0.04
Manganese, mg/L Mn	-	0.05	<0.005	0.005	0.007	0.005	0.005	<0.005
Mercury, mg/L Hg	0.002	-	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nickel, mg/L Ni	-	-	0.020	<0.010	0.010	0.010	<0.005	0.010
Selenium, mg/L Se	0.01	-	0.008	0.003	0.0008	0.008	0.002	0.0019
Silver, mg/L Ag	0.05	-	0.002	0.001	<0.001	0.003	0.001	0.002
Sodium, mg/L Na	-	-	89	92	93	90	98	91
Zinc, mg/L Zn	-	5.0	0.013	0.005	0.041	0.033	0.007	0.001
TOC, mg/L C	-	-	2.24	1.40	1.58	1.36	1.11	1.99
Bromide, mg/L Br	-	-	0.14	0.19	0.23	0.45	0.21	0.44
Total Coliform, MPN/100 mL	-	-	<2	<2	<2	<2	<2	<2
Fecal Coliform, MPN/100 mL	-	-	<2	<2	<2	<2	<2	<2
Fecal Strep, MPN/100 mL	-	-	<2	<2	<2	<2	<2	<2
Total Plate Count/mL	-	-	<0.5	<0.5	<0.5	1.0	<0.5	<0.5

Footnotes - see page A-16.

TABLE A-13

CHEMICAL AND BACTERIAL WATER QUALITY CHARACTEFISTICS OF STUDY SAMPLING SITES (a)

Parameter	Interim Primary Drinking Standard(b)	Secondary Drinking Water (c)	Anaheim Well 29 $UnCl_2$			Anaheim Well 22 $UnCl_2$		
			#27 10/22/79	#62 9/11/80	#75 11/10/80	#26 10/15/79	#63 9/15/80	#76 11/12/80
Turbidity, NTU	0.5-5(d)	5	<0.10	0.10	0.04	0.1	0.2	0.53
Color, CU	-	15	<5	5	5	<5	5	<5
pH	-	-	7.73	8.02	7.92	7.88	7.33	8.01
Dissolved Solids, mg/L	-	500-1500(e)	190	667	601	701	683	668
Total Alkalinity, mg/L $CaCO_3$	-	-	214	214	206	204	189	190
Chloride, mg/L Cl	-	250-600(f)	96	94	66	100	98	69
Sulfate, mg/L SO_4	-	250-600(g)	152	150	140	199	200	210
Nitrate, mg/l N	10.0	-	3.75	4.74	4.40	2.79	2.65	2.97
Nitrite, mg/L N	-	-	0.002	0.001	<0.001	<0.001	<0.001	<0.001
Ammonia, mg/L N	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Phosphate, mg/L PO_4	-	-	0.1	0.09	0.38	0.12	0.04	1.28
Fluoride, mg/L F	1.4-2.4(h)	-	0.58	0.57	0.45	0.50	0.54	0.51
Cyanide, mg/L CN	-	-	0.01	<0.01	0.01	<0.01	0.07	<0.01
Total Hardness, mg/L $CaCO_3$	-	-	319	314	313	372	376	360
Arsenic, mg/L As	0.05	-	0.002	0.004	0.0015	0.008	0.002	0.0016
Barium, mg/L Ba	1.0	-	0.54	0.50	0.21	0.50	0.5	0.25
Cadmium, mg/L Cd	0.01	-	0.003	<0.001	0.002	0.001	0.001	0.004
Chromium, mg/L Cr	0.05	-	<0.010	0.003	<0.001	0.006	<0.001	<0.001
Copper, mg/L Cu	-	1.0	0.005	<0.005	0.015	0.005	<0.005	<0.005
Iron, mg/L Fe	-	0.3	0.01	0.02	0.02	0.04	0.02	<0.01
Lead, mg/L Pb	0.05	-	0.01	<0.01	0.01	0.03	0.02	0.04
Manganese, mg/L Mn	-	0.05	<0.005	<0.005	0.006	<0.005	<0.005	<0.005
Mercury, mg/L Hg	0.002	-	<0.0001	<0.0001	<0.0001	<0.0001	0.0002	<0.0001
Nickel, mg/L Ni	-	-	0.02	0.005	0.010	0.010	0.010	0.008
Selenium, mg/L Se	0.01	-	0.006	<0.001	0.002	0.011	0.001	0.0045
Silver, mg/L Ag	0.05	-	<0.001	0.002	0.001	0.002	0.002	0.002
Sodium, mg/L Na	-	-	89	86	83	84	71	78
Zinc, mg/L Zn	-	5.0	<0.001	0.014	0.032	0.029	<0.001	<0.001
TOC, mg/L C	-	-	0.56	0.51	0.79	0.67	0.46	0.42
Bromide, mg/L Br	-	-	0.22	0.24	0.25	0.21	0.22	0.30
Total Coliform, MPN/100 mL	-	-	<2	<2	<2	<2	<2	<2
Fecal Coliform, MPN/100 mL	-	-	<2	<2	<2	<2	<2	<2
Fecal Strep, MPN/100 mL	-	-	<2	<2	<2	<2	<2	<2
Total Plate Count/mL	-	-	<0.5	<0.5	15	2.5	$2.8X10^4$	5.5

Footnotes - see page A-16.

TABLE A-14

CHEMICAL AND BACTERIAL WATER QUALITY CHARACTERISTICS OF STUDY SAMPLING SITES(a)

Parameter	Interim Primary Drinking Standard(b)	Secondary Drinking Water (c)	OCWD Water Factory 21 Q9		OCWD Water Factory 21 R.O.	
			#13* 4/04/79	#65* 9/18/80	#64* 9/18/80	#77** 11/17/80
Turbidity, NTU	0.5-5(d)	5	0.1	0.2	0.1	0.04
Color, CU	-	15	<5	<5	<5	<5
pH	-	-	6.92	7.12	7.17	7.16
Dissolved Solids, mg/L	-	500-1500(e)	958	953	63	90
Total Alkalinity, mg/L $CaCO_3$	-	-	64	38	14	20
Chloride, mg/L Cl	-	250-600(f)	250	342	29	31
Sulfate, mg/L SO_4	-	250-600(g)	267	210	4	5.5
Nitrate, mg/L N	10.0	-	10.50	0.02	0.46	0.4
Nitrite, mg/L N	-	-	<0.001	<0.001	0.211	0.129
Ammonia, mg/L N	-	-	<0.1	16.5	0.7	2.2
Phosphate, mg/L PO_4	-	-	0.30	0.25	0.03	0.02
Fluoride, mg/L F	1.4-2.4(h)	-	0.80	0.59	0.16	0.16
Cyanide, mg/L CN	-	-	<0.01	0.01	0.01	0.01
Total Hardness, mg/L $CaCO_3$	-	-	290	221	3	2
Arsenic, mg/L As	0.05	-	0.001	0.003	0.001	<0.0005
Barium, mg/L Ba	1.0	-	0.23	0.10	<0.01	<0.01
Cadmium, mg/L Cd	0.01	-	0.011	<0.001	<0.001	<0.001
Chromium, mg/L Cr	0.05	-	0.015	0.005	<0.001	0.010
Copper, mg/L Cu	-	1.0	0.025	0.070	<0.005	<0.005
Iron, mg/L Fe	-	0.3	0.02	0.01	0.04	<0.01
Lead, mg/L Pb	0.05	-	0.01	0.03	<0.01	<0.01
Manganese, mg/L Mn	-	0.05	<0.005	<0.005	<0.005	<0.005
Mercury, mg/L Hg	0.002	-	<0.0001	<0.0001	<0.0001	<0.0001
Nickel, mg/L Ni	-	-	0.040	0.020	0.005	<0.005
Selenium, mg/L Se	0.01	-	0.006	0.002	<0.001	0.0062
Silver, mg/L Ag	0.05	-	0.001	0.003	<0.001	<0.001
Sodium, mg/L Na	-	-	175	220	20	19
Zinc, mg/L Zn	-	5.0	0.006	0.069	0.004	0.002
TOC, mg/L C	-	-	6.64	-	0.40	0.61
Bromide, mg/L Br	-	-	0.99	0.92	0.09	0.14
Total Coliform, MPN/100 mL	-	-	<2	<2	4	11
Fecal Coliform, MPN/100 mL	-	-	<2	<2	4	<2
Fecal Strep, MPN/100 mL	-	-	<2	<2	<2	<2
Total Plate Count/mL	-	-	<0.5	<0.5	66	34

* Chlorinated ** Unchlorinated

Footnotes - see page A-16.

TABLE A-15

CHEMICAL AND BACTERIAL WATER QUALITY CHARACTERISTICS OF STUDY SAMPLING SITES (a)

Parameter	Interim Primary Drinking Water Standard(b)	Secondary Drinking Water Standard (c)	OCWD Well M-10 UnCl$_2$			OCWD Well M-12 UnCl$_2$		
			#30 11/05/79	#66 9/25/80	#78 11/25/80	#29 10/29/79	#67 9/30/80	#79 12/02/80
Turbidity, NTU	0.5-5(d)	5	0.4	4.3	0.46	0.3	4.3	0.30
Color, CU	-	15	<5	5	5	<5	5	5
pH	-	-	8.09	7.76	8.06	8.03	7.76	7.79
Dissolved Solids, mg/L	-	500-1500(e)	366	395	362	410	476	369
Total Alkalinity, mg/L $CaCO_3$	-	-	142	130	253	151	173	179
Chloride, mg/L Cl	-	250-600(f)	63	70	94	69	64	55
Sulfate, mg/L SO_4	-	250-600(g)	70	71	68	80	65	54
Nitrate, mg/l N	10.0	-	1.38	1.94	1.33	2.14	1.89	1.23
Nitrite, mg/L N	-	-	0.011	0.010	0.007	0.023	0.009	0.007
Ammonia, mg/L N	-	-	<0.1	<0.1	0.2	<0.1	<0.1	<0.1
Phosphate, mg/L PO_4	-	-	0.16	0.19	0.20	0.10	0.13	0.12
Fluoride, mg/L F	1.4-2.4(h)	-	0.44	0.49	0.43	0.43	0.50	0.48
Cyanide, mg/L CN	-	-	<0.01	<0.01	0.01	<0.01	0.01	<0.01
Total Hardness, mg/L $CaCO_3$	-	-	162	164	145	188	204	190
Arsenic, mg/L As	0.05	-	0.003	0.002	0.006	0.003	0.001	0.0023
Barium, mg/L Ba	1.0	-	0.22	0.24	0.16	0.36	0.31	0.22
Cadmium, mg/L Cd	0.01	-	0.001	0.001	0.002	0.002	0.001	0.003
Chromium, mg/L Cr	0.05	-	<0.001	<0.001	0.008	<0.001	<0.001	0.001
Copper, mg/L Cu	-	1.0	<0.005	<0.005	0.005	<0.005	0.008	0.005
Iron, mg/L Fe	-	0.3	0.74	0.60	0.12	0.04	0.04	0.06
Lead, mg/L Pb	0.05	-	0.02	<0.01	<0.01	<0.01	<0.01	0.08
Manganese, mg/L Mn	-	0.05	0.030	0.029	0.022	0.005	0.008	0.01
Mercury, mg/L Hg	0.002	-	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nickel, mg/L Ni	-	-	<0.005	<0.005	0.005	<0.010	0.01	0.008
Selenium, mg/L Se	0.01	-	0.010	<0.001	0.0012	0.007	<0.001	<0.0005
Silver, mg/L Ag	0.05	-	0.001	0.002	<0.001	0.002	0.002	<0.001
Sodium, mg/L Na	-	-	67	64	72	62	56	51
Zinc, mg/L Zn	-	5.0	0.011	0.014	0.021	0.007	0.046	0.036
TOC, mg/L C	-	-	0.86	0.74	1.81	0.91	0.55	0.86
Bromide, mg/L Br	-	-	0.11	0.13	0.08	0.12	0.20	0.12
Total Coliform, MPN/100 mL	-	-	<2	<2	<2	<2	<2	<2
Fecal Coliform, MPN/100 mL	-	-	<2	<2	<2	<2	<2	<2
Fecal Strep, MPN/100 mL	-	-	2	<2	<2	<2	2	<2
Total Plate Count/mL	-	-	73.0	92	435	470.0	$2.5 \times 10_4$	22

Footnotes - see page A-16.

TABLE A - FOOTNOTES

CHEMICAL AND BACTERIAL WATER QUALITY CHARACTERISTICS OF STUDY SAMPLING SITES

(a) Sampling sites in Los Angeles County include the Los Angeles County Sanitation Districts' San Jose Creek, Whittier Narrows, and Pomona Water Reclamation Plants (chlorinated/dechlorinated filtered effluent, chlorinated and unchlorinated activated sludge effluent), the Los Angeles/Glendale Water Reclamation Plant (disinfected filtered effluent), Metropolitan Water District's Colorado River water and State Project water feeders to the Rio Hondo and San Gabriel River, storm water collected at the Rio Hondo Spreading Grounds, Montebello Forebay Wells 1591H, 2947Q, 1621MM, 1514A, 1580J, 1566A, 1620GG, 2958A, 2907, 1562E, the Department of Water and Power Hollywood Wells Collector and Pollack Wells, and dry water runoff collected in the Los Angeles River. Sites in Orange County include the Orange County Water District's Water Factory 21 (Q_9 - activated carbon effluent and reverse osmosis effluent) and injection barrier observation wells M-10 and M-12, and Anaheim Forebay Wells - Yorba Linda 11 and Anaheim Wells 27, 29, and 22.

(b) Article 4, Section 64435, Maximum Contaminant Levels, California Domestic Water Quality and Monitoring Regulations, Title 22, California Administrative Code, 1977.

(c) Article 8, Section 64473, Maximum Contaminant Levels, California Domestic Water Quality and Monitoring Regulations, Title 22, California Administrative Code, 1977.

(d) Article 4, Section 64435, Subsections (f) and (g), Maximum Contaminant Levels, California Domestic Water Quality and Monitoring Regulations, Title 22, California Administrative Code, 1977.

(e) Article 8, Section 64473, Subsection (a), Maximum Contaminant Levels, California Domestic Water Quality and Monitoring Regulations, Title 22, California Administrative Code, 1977.

(f) Article 8, Section 64473, Subsection (a), Maximum Contaminant Levels, California Domestic Water Quality and Monitoring Regulations, Title 22, California Administrative Code, 1977.

(g) Article 8, Section 64473, Subsection (a), Maximum Contaminant Levels, California Domestic Water Quality and Monitoring Regulations, Title 22, California Administrative Code, 1977.

(h) Article 4, Section 64435, Subsection (a), Maximum Contaminant Levels, California Domestic Water Quality and Monitoring Regulations, Title 22, California Administrative Code, 1977.

(i) Sample collected from Hollywood Well No. 5.

APPENDIX B

VIRUSES IN GROUNDWATER - LITERATURE REVIEW

INTRODUCTION

It is projected that groundwater which constitutes 95 percent of the nation's fresh-water supply, will provide approximately one-third of the total water consumed in the United States by the year 2000 (B-1). For the most part, groundwater supplies have been considered free of contaminating chemicals and pathogenic microorganisms because of the removal of these substances as water percolates through the soil. This assumption is known as the living filter theory. However, the recent discovery of contaminating compounds in groundwater supplies throughout the country has resulted in a reevaluation of the living filter theory, particularly in situations such as the land application of wastewater or solid waste where contamination may inadvertently occur.

Investigators concerned with the impact of wastewater reuse on groundwater quality are attempting to determine which contaminants in reclaimed water may be removed by soil percolation and what the active mechanisms of removal may be. Akin (B-2) points out that the risks of exposure to microbial pathogens increases with the application of domestic waste to the land. While he was referring to sludges, the same contaminants may be found in wastewater, although usually at lower concentrations. Viruses are one group of pathogens about which little is known. This section of the report reviews the reasons for concern about virus contamination of the environment and provides an in-depth summary regarding the potential for virus transmission through wastewater disposal.

THE SIGNIFICANCE OF VIRUS IN THE ENVIRONMENT

There are more than 100 types of enteric viruses that can be transient inhabitants of the human lower intestinal tract. Information regarding the significance of these pathogens as environmental pollutants is difficult to evaluate. Melnick (B-3) stated that for proper documentation of viral outbreaks the infection must have a short and uniform incubation period and produce a characteristic, easily recognizable disease. Under these conditions, the pathogen and source of dissemination into the population would be easy to identify.

Infections caused by enteroviruses do not usually follow such a recognizable pattern. Goldfield (B-4) lists four problems confronting the epidemiologist's attempt at discerning an enterovirus outbreak. The first is that a substantial portion of the exposed population would probably possess prior immunity and therefore not acquire any infection. Second, only a portion of those people infected by virus would actually develop symptoms. Third, the diverse nature of the symptoms associated with many viral diseases would present a pattern so varied that a clinical picture implicating a single etiologic agent becomes almost impossible. Finally, even if the etiologic agent were identified, recognition of the source of diffusion of the agent into the community would be difficult to determine because of secondary person-to-person spread. As a result of these epidemiological problems, only a few cases of waterborne virus outbreaks have been confirmed. The virus implicated in these outbreaks was hepatitis. The pathology of hepatitis is such that documentation of its presence is possible.

GROUNDWATER CONTAMINATION BY VIRUS

Keswick and Gerba (B-5) extensively reviewed the literature on virus contamination of groundwater. They divided the contamination incidents into: a) those that occurred as the result of replenishment projects or land application of wastewater and b) those that were the result of accidental contamination. This review incorporates the work of Keswick and Gerba and documents the known contamination incidents in terms of water quality criteria. In many cases, the author's data have been further reduced and reported as probability medians.

Groundwater Contamination by Land Application

Wellings reported on two studies involving groundwater contamination in Florida. The first (B-6) of these describes a disposal situation in which chlorinated secondary effluent from a package treatment plant serving a 154 unit mobile home park was discharged onto a cypress dome. The travel time from the plant to the discharge point ranged between 0.5 to 1.5 hours. Available data indicated that the plant influent had a median virus level of 290 pfu/gal. Eight of 15 effluent samples tested contained viruses; the median concentration was 0.062 pfu/gal. Evaluation of the disinfection efficiency of the package plant was not possible due to a lack of coliform data.

The cypress dome covered an area of approximately 55,000 square feet and had a holding capacity of about 378,000 gallons of water. The first 2 feet of soil in the dome consisted of black organic material containing 12 percent clay. The clay content decreased to 4 percent in the underlying natural sand layer which was about 4 feet deep. The first confining layer of soil occurred at a depth of 6 to 7 feet and consisted of an organic base containing 32 percent clay. Below this layer was a 6 foot layer of tan to gray sand that was underlain by blue-gray sand with 5 to 19 percent clay. Nonpermeable blue clay was evident at the 17 to 18 foot depth precluding any significant verticle flow below that level.

A total of 78 virus samples were collected from monitoring wells around the cypress dome. Viruses were isolated from three of the samples. The well locations showing viral contamination were located at lateral and vertical distances of 124 feet and 10 feet, respectively from the discharge point.

Coliform levels or other bacterial indices for the well water were not routinely determined during this study. Personal communications, however, indicated that in at least one case, fecal coliforms (13/100 mL) were detected in a well sample.

A second study reported by Wellings et al. (B-7) demonstrated viral contamination of groundwater resulting from spray irrigation of wastewater in Florida. Soil in the project area was described as sandy. The irrigation water was chlorinated secondary effluent of apparent low quality. Coliform data were again not available but virus levels in the effluent ranged from 23 to 800 pfu/gal.

Four 50 gallon well samples were collected from a depth of about 10 feet at the irrigation site. Viruses were detected in all four samples with concentrations ranging from 0.02 to 1.5 pfu/gal. Three more samples were collected from a 20 foot well following a rain storm with the following results: 1) sixty-eight pfu were recovered from a 100 gallon sample collected the morning of the first day of sampling, 2) another 100 gallon sample taken that afternoon yielded 16 pfu, and 3) a 100 gallon sample taken the following morning was negative. Wellings indicated that the most significant aspect of the data from the 20 foot well was that it demonstrated virus movement in the soil as a result of rain-water elution.

Vaughn and Landry have done extensive research on virus contamination in Long Island, New York. One study (B-8) involved three treatment facilities, the Meadowbrook, Stony Brook and Parkland treatment plants. Effluent from all three treatment plants is discharged into a series of replenishment basins and eventually becomes part of the groundwater supply.

Meadowbrook is a trickling filter plant which provides chlorination as a final treatment step. At the time the study was conducted, the water table in the area of the Meadowbrook replenishment basin was about 30 feet deep. A 37 foot observation well was installed approximately 10 feet down gradient from the basin. Effluent from the Meadowbrook plant contained median total and fecal coliform concentrations of 5,500/100 mL and 270/100 mL, respectively. Viruses were isolated from three of 12 effluent samples; reported virus levels were 6.4, 80 and 100 pfu/gal. Groundwater samples collected from the observation well were also positive for coliforms and viruses. Median total and fecal coliform concentrations were 95/100 mL and 7/100 mL, respectively. Viruses were isolated from three of 10 well samples at concentrations of 1.3, 2.4 and 3.6 pfu/gal.

The Stony Brook facility is a contact stabilization plant discharging chlorinated secondary effluent. The groundwater table in the vicinity of the plant's replenishment basin is about 80 feet below the ground surface. An 84 foot observation well was located approximately 8 feet down gradient from the recharge site. The Stony Brook chlorinated effluent contained median total coliform concentrations of 6,500/100 mL and fecal coliform levels of 2000/100 mL. Viruses were detected in four of 12 effluent samples at concentrations of 23, 32, 84, and 370 pfu/gal. The quality of groundwater impacted by the Stony Brook recharge basin appeared to be somewhat degraded as evidenced by total and fecal coliform concentrations of 280/100 mL and 0.2/100 mL, respectively; however, no viruses were detected in nine well samples.

The Parkland treatment plant is a tertiary facility which includes activated sludge extended aeration, denitrification, sand filtration and chlorination. The authors reported that the plant experienced repeated operational difficulties. Effluent was discharged into a replenishment basin; the underlying water table was at a depth of 18 feet. A 20 foot observation well was located about 150 feet down gradient from the basin. Due to operational problems, the Parkland plant had the lowest quality effluent of all the facilities evaluated with median total and fecal coliform concentrations of 21,000/100 mL and 4,000/100 mL, respectively. The Parkland effluent also yielded the greatest number of virus isolations with six of 11 samples positive. Virus concentrations ranged from 6.8 to 1,100 pfu/gal. Groundwater samples from the Parkland site also contained the greatest number of viruses. Three out of 10 well samples were positive with concentrations of 1.6, 3.7, and 11.0 pfu/gal.

This study established that viruses discharged in a chlorinated effluent could contaminate groundwater supplies. Individual sample coliform concentrations did not correlate with virus isolations even though the median coliform levels in all three effluents were indicative of very low quality water.

Another recharge project evaluated by Vaughn and Landry (B-9) involved the 12-Pines, New York tertiary treatment plant. The treatment scheme at this facility consisted of conventional primary and secondary treatment with denitrification followed by filtration through a mixed bed of garnet, quartz and anthracite media. The chlorinated effluent was discharged into a series of replenishment basins totaling some 2.5 acres. A portion of the flow was diverted into a specially constructed test basin for sampling purposes. Soil in the basin consisted of coarse sand and fine gravel with an average of 1.12 percent silt and clay. A manhole was constructed in the center of the basin to provide access to a series of in situ sampling pans buried at depths of approximately 2.5, 7, and 17.5 feet and an observation well which tapped the groundwater table at approximately 25 feet.

Overall, the effluent from the 12-Pines plant was of notably higher quality than the effluent qualities reported in the previous studies. The median effluent total coliform level was 15/100 mL and the fecal coliform probability median was 0.03/100 mL. However, this effluent quality was not always reliably produced as evidenced by individual effluent coliform concentrations ranging as high as 3.8×10^5/100 mL. Viruses were isolated from four of 28 effluent samples with concentrations ranging from 1 to 310 pfu/gal.

Samples collected from the observation well in the test basin contained moderately high coliform levels; six of 28 samples were found to contain viruses. Median total and fecal coliform concentrations were 140/100 mL and 9.5/100 mL, respectively. Virus levels in the positive samples ranged from 0.5 pfu/gal to 2.5 pfu/gal.

As part of this study the authors also conducted experiments with vaccine strain polio virus seeded into the treatment plant effluent to evaluate virus removal during percolation. They reported that the soil in the basin effectively adsorbed the majority of the seeded viruses and that increasing the infiltration rate resulted in an increase in the number of viruses reaching the groundwater.

As an adjunct to the field portions of this study, the authors also conducted laboratory soil column experiments using soil cores from different sites on Long Island. They reported that the adsorptive capacity of the soil was dependent on the nature of the virus, the chemical composition of the soil and the applied water, and the moisture content of the soil. Finally, they indicated that after adsorption, the viruses could be mobilized by flooding the columns with rain water or sewage effluents.

Moore et al. (B-10) presented the findings of a study in the south central Texas city of Kerrville which evaluated the use of reclaimed water for agricultural irrigation. Reclaimed water was produced by a 1.4 MGD secondary treatment plant. The treatment train consisted of an oxidation ditch with final clarification. A portion (0.6 MGD) of the oxidation ditch effluent passed through a trickling filter prior to entering the clarifier. Effluent from the clarifiers was discharged into a storage pond for the project's sprinkler irrigation system. Effluents were not disinfected prior to use.

Soils at the irrigation site were characterized as well drained and varied from loams to clays. Soil tests indicated a permeability of 1.5 to 5.1 cm/hr, a pH of 7.7 to 9.0 and a cation exchange capacity of 25 to 50 meq/100 g. Specially designed PVC lysimeters were installed at varying depths down to 4.5 feet, and wells were drilled to depths ranging from 36 to 66 feet to facilitate sampling at the irrigation site. Depth of groundwater in the area varied from 12 to 17 feet.

Total and fecal coliforms in the plant effluent averaged 1.3×10^7/100 mL and 2.5×10^6/100 mL. Some coliform dieoff occurred in the holding pond; the bacterial population decreased slightly more than one order of magnitude. Average virus levels in the effluents ranged from 4.7 to 21 pfu/gal. The authors reported that there was some difficulty in measuring virus concentrations in the holding pond due to a large algae population.

The lysimeter samples generally showed a decreasing coliform population with increasing depth in the soil. However, total and fecal coliform concentrations in samples from the deepest lysimeter did range as high as 3.1×10^6/100 mL and 7.8×10^5/100 mL, respectively. Median bacterial levels in the five monitoring wells ranged from 20 to 3100/100 mL (total coliforms) and 2.4 to 370/100 mL (fecal coliforms) indicating probable contamination from the irrigation project. Although viruses were isolated from the lysimeter samples on numerous occasions, no viruses were detected in the well samples during this study.

Schaub and Sorber (B-11) investigated a rapid infiltration system at Fort Devens, Massachusetts. This Army facility discharged non-disinfected Imhoff tank effluent into rapid infiltration cells. Due to clogging problems, the top one to 4 foot layer of the infiltration site was replaced with sand and gravel. The underlying soil was unconsolidated silty sand and gravel, of glacial origin, over bedrock. A number of observation wells were constructed at depths ranging from 11 to 108 feet; five of these were sampled for virus.

The average virus concentration of seven effluent samples was 930 pfu/gal. No bacterial data were reported. Viruses were subsequently isolated from the majority of samples collected from the wells. Virus concentrations in the positive wells ranged from 5 to 140 pfu/gal. This study documented vertical and lateral migration distances of 108 feet and 600 feet, respectively.

In a similar study, Koerner et al. (B-12) detected viruses in samples collected at a depth of 55 feet and 820 feet away from a rapid infiltration site in New Jersey. Primary effluent (not disinfected) was applied to a sandy-gravelly soil. Fecal coliforms were not detected in any samples collected at depths below 30 feet indicating that the viruses were able to migrate much further than the bacteria.

At Flushing Meadows, near Phoenix, Arizona, Gerba et al. (B-13) studied the viral removal capability of the local soil which was characterized as fine loamy sand over coarse sand and gravel. The replenishment water was undisinfected activated sludge effluent; average total coliform concentrations were > 240,000/100 mL while average fecal coliform concentrations were 28,000/100 mL. Virus levels in the effluent ranged from 160 to 480 pfu/gal. Twelve samples were assayed from observaton wells ranging in depth from 60 to 100 feet. Virus concentrations were reported to be 1 to 2 pfu/100 gal. Other well samples remained to be assayed at the time of this writing.

Goyal, Keswick, and Gerba (B-14) also evaluated effluent from an activated sludge plant in Lubbock, Texas used for spray irrigation. In this case, chlorinated and unchlorinated effluents were blended in a one to one ratio and were stored in lagoons prior to use. Total coliform levels in the lagoons were consistently greater than 100/100 mL; one 10 liter lagoon sample tested for virus contained 21 pfu. Virus samples were also collected from four wells. All of the wells had positive results with concentrations ranging from 2 to 6 pfu/100 gal. Seven soil samples were evaluated for virus with five of the seven samples yielding positive results.

At a site in San Angelo, Texas (8-14) secondary effluent was applied to a 640 acre farm by flood irrigation. The effluent was held in lagoons up to seven days prior to application. (The report did not indicate whether the reclaimed water was disinfected prior to use). Well samples at the site contained moderately high levels of coliform bacteria. Total coliform concentrations ranged from 30 to 620/100 mL with some values reported as "too numerous to count" (TNTC). Fecal coliforms were also present ranging from < 1 to 250/100 mL with three samples reported as TNTC. Viruses were isolated from four of seven well samples collected at depths of 30 to 90 feet.

Goyal et al. (B-14) reported on a land treatment project in Muskegon, Michigan where aerated lagoon effluent was applied by a spray irrigation to an 11,000 acre farm and collected in an underdrain system for disposal. Soil at the spray irrigation site was characterized predominantly as Rubicon sand. Viruses were isolated from storage lagoon samples and from one of nine observation wells tested. Of three soil samples assayed, one was virus positive. Coliform concentrations in the storage lagoon were described as TNTC at the test dilutions employed. Total coliform levels observed in on-site wells were high; fecal coliforms were detected in two of eight well samples. Viruses were isolated from one well sample.

Accidental Groundwater Contamination

The second group of documented viral isolations in groundwater occurred as the result of accidental contamination. Although not directly related to planned reuse, these cases provide information about routes of virus migration.

During an outbreak of gastrointestinal illness at a migrant labor camp, Wellings (B-15) isolated echovirus 22/23 from a well serving the camp. The well was 40 feet deep and was located 100 feet from a solid waste drain field. The area was also surrounded by septic tanks. A chlorine residual of 0.4 to 0.6 mg/L was maintained in the otherwise untreated water and no coliforms were detected. This incident occurred approximately six weeks before a hepatitis A outbreak at the same camp.

Mack et al. (B-16) investigated an outbreak of gastrointestinal illness involving restaurant patrons in a town in Michigan. Potable water was supplied to the restaurant by a well. The water was chlorinated and test data indicated coliform levels ranging from < 1 to 16 MPN/100 mL. Although the author isolated poliovirus type 2 from the well, it was not implicated with the disease outbreak. The author suggested that the presence of poliovirus and the occurrence of gastroenteritis could be traced to contamination by a drainfield located 300 feet from the well. Soil in the area consisted of an 18 foot layer of clay which capped an 8 foot layer of shale underlain by a 74 foot layer of limestone.

Marzouk et al. (B-17) isolated coxsackie B6, echo 6 and 7, polio 1 and several unidentified viruses from groundwater in Israel. Samples were collected from wells at depths of about 10 feet which were located in an area impacted by septic tank discharges and other sources of sewage contamination. Viruses were isolated from 20 of the 99 samples collected during this study. Total plate count levels ranged as high as 10^4 cells/mL; the probability median was 350 cells/mL. Fecal coliform concentrations, however, were much lower. Fecal coliforms were detected in only five of the positive virus samples. Fecal streptococci were also isolated in a few of the samples. The authors pointed out that 13 of the positive virus samples met local coliform standards. Although not clearly stated in the article, it was implied that the cited standard of $\leq$ 2/100 mL was for fecal coliforms.

Rao et al. (B-18) tested drinking water supplies at a number of locations in India. At Nagpur, samples were collected from wells and from the community water distribution system. Viruses were isolated from five of nine well samples and from seven of 50 samples collected from the distribution system. The samples from the water distribution system contained a chlorine residual ranging from 0.2 to 0.8 mg/L; coliform levels were < 1/100 mL. Turbidity data from three of the Nagpur samples ranged from 1 to 9.2 JTUs. It was Rao's opinion that the presence of viruses in the distribution system was the direct result of sewage infiltration.

As another part of Rao's study (B-18), samples were collected from the water supplies of three towns experiencing outbreaks of infectious hepatitis. Enteric viruses were detected in approximately half of the samples collected. Corroborative coliform data were not reported. At one of the sites (Bombay) there was no measurable chlorine residual and the turbidity averaged 9.4 JTUs.

The Keswick and Gerba review paper (B-5) briefly discussed five additional cases of reported virus isolations from groundwater. These incidents occurred in England, Germany, Israel, Ghana and China. Correlative water quality data were generally not available for these cases.

MOVEMENT OF VIRUS THROUGH SOIL

All of the virus isolation incidents discussed in this review had a common element; namely, regardless of the source of contamination, virus migration occurred. Various physical and chemical factors are known to affect virus migration through soils. These factors have been studied by a number of researchers (B-9, B-19, B-20, B-21, B-22, B-23).

Drewry et al. (B-19) conducted experiments with soil columns and bacteriophage. These studies showed that the major factors influencing viral adsorption were the pH and salt content of the solute and such soil characteristics as clay content, silt content, ion exchange capacity and glycerol retention. The authors concluded that at pH 7.5, or below, adsorption was rapid and more efficient than at higher pH values, and that adsorption increased as clay content, silt content, ion exchange capacity and glycerol capacity of the soil increased.

Wang et al. (B-20) studied the effect of hydraulic flow rates on the adsorption capacity of Flushing Meadows sand, Rubicon sand, Pomello sand and Anthony sandy loam in 4 cm diameter, 100 cm long columns. The greatest amount of virus adsorption occurred in the Pomello sand which had the highest organic content and highest percent pore space of the different soils. The least amount of adsorption occurred in the Rubicon sand which had the lowest organic content and lowest percent pore space. Virus removal was shown to be inversely related to flow rate, while removal in the upper part of the column was significantly greater than in the lower part. The authors concluded that soil permeability may be one of the most important factors in determining the potential for virus movement through soil.

The findings of Wang were confirmed to a degree by Vaughn et al. (B-9). Vaughn's work was cited earlier in the discussion regarding the Long Island projects. These experiments, which evaluated the effects of varying the infiltration rate on virus removal, indicated that removal efficiency improved as the flow rate decreased.

Lance and Gerba (B-21) demonstrated that the adsorption of poliovirus type 1 was also flow dependent. Seeded secondary effluent was percolated through calcareous sand in 250 cm columns. Results from previous studies had shown that increasing the application rate from 0.15 to 0.55 m/day had no effect on virus movement. In this particular experiment, virus movement was observed following an increase in the application rate from 0.6 to 1.2 m/day, although movement did not alter significantly with further increases in application (1.2 to 12.0 m/day).

In addition to soil characteristics and infiltration rate, it has been demonstrated that different virus types have different adsorption characteristics. Gerba and Goyal (B-22) studied the relative adsorption of 27 different viruses on nine soil types. Landry (B-23) tested five virus types on cores from the Long Island replenishment basins previously mentioned. Both studies found that most of the poliovirus was removed, but that coxsackie and echoviruses exhibited varied adsorption patterns. The source of the virus, i.e., whether laboratory culture or natural isolate, also affected adsorption.

In addition to specific adsorption characteristics, Landry, Wellings and Gerba (B-7, B-22, B-23) all reported that once viruses were adsorbed to various soils, mobilization could occur following heavy rains or application of various low-ionic fluids.

Factors affecting virus survival in soil systems have also been investigated (B-5). Studies have shown that soil characteristics such as texture, organic content, pH, presence of cations, and adsorptive capacity are important factors associated with virus survival. The type of virus and the potential for microbial antagonism have been listed as other important factors. Finally, climatic factors also effect virus survival including the amount of rainfall, temperature, sunlight, and potential for dessication.

SUMMARY

This review has discussed numerous incidents of viral contamination of groundwater supplies associated with both intentional reuse and accidental contamination. It has also focused on the many factors affecting virus migration and survival in the soil.

It appears that three general observations can be derived from the information presented herein. First, and most important, viruses can and do migrate through soil systems into groundwater supplies. Although mitigation may occur given the proper conditions, the soil cannot be considered as a dependable barrier against viral contamination. Second, viruses once adsorbed to soil particles may desorb. This can occur after a rain storm or after the application of other low-ionic strength waters to a disposal site and could potentially result in transient spikes of relatively high virus concentrations in groundwater. The third observation is that traditional water quality indicators such as coliform bacteria do not necessarily provide adequate indices of viral contamination in groundwater.

The significance of these three conclusions is that if groundwater potability is of concern, then viruses should be reliably eliminated from wastewater during treatment, prior to discharge or reuse. A conservative approach would dictate that the soil be considered only as a secondary safety barrier to viral migration and not a primary means of virus removal or mitigation.

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APPENDIX C

METHODS FOR VIRUS AND LARGE VOLUME COLIFORM SAMPLING

VIRUS CONCENTRATION

A self-contained, truck-mounted, portable virus concentrator was developed at the Sanitation Districts for use in this Study. The unit was basically a modification of the Wallis-Melnick (C-1) electrostatic concentrator. Developmental data have been reported elsewhere (C-2, C-3). The unit was capable of concentrating up to 1000 gallons of well water and 300 to 500 gallons of wastewater. Virus recovery using the concentrator averaged 83 percent for potable water and 42 percent for reclaimed water as determined with seeded polio virus.

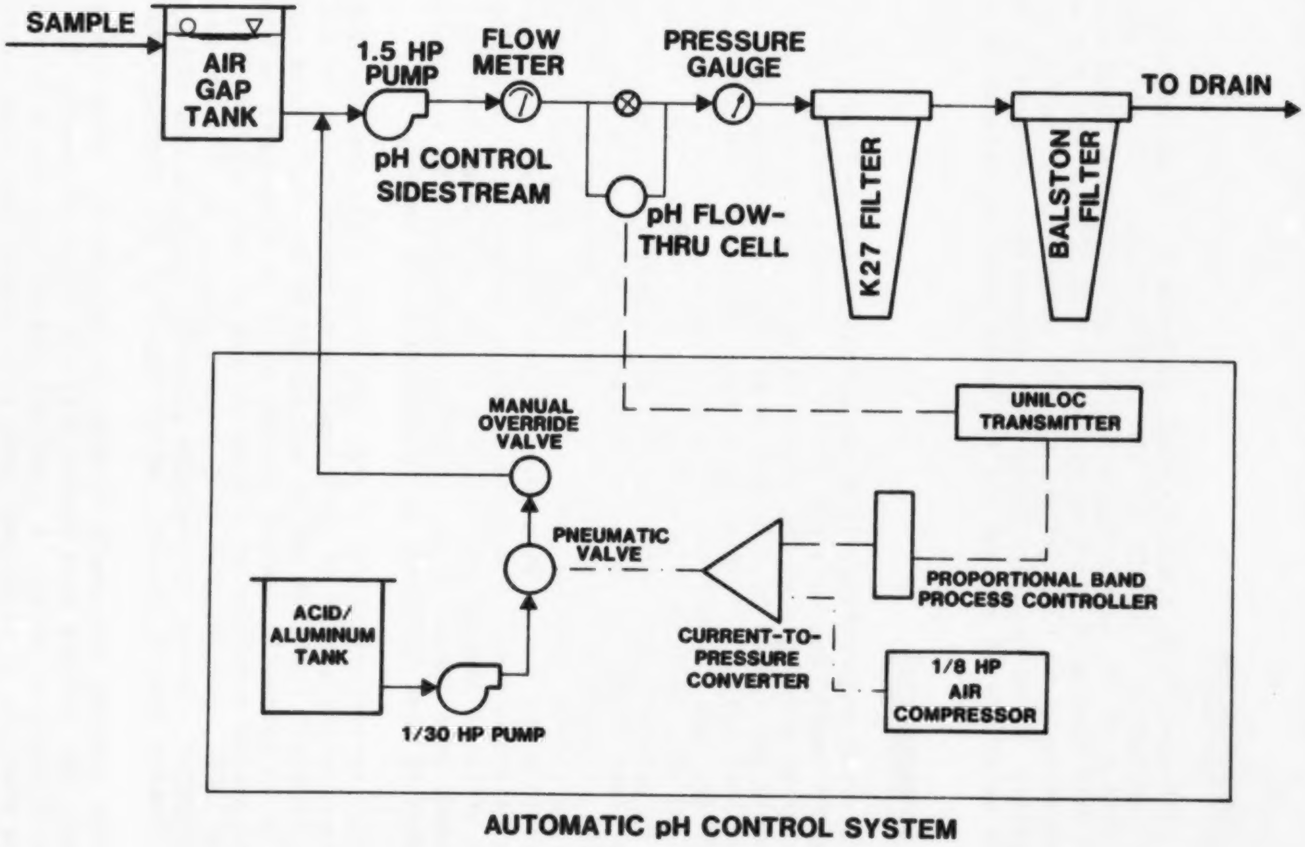
Field Concentration

The virus concentrator is shown schematically in Figure C-1. A water or wastewater sample was obtained either by directly hooking up to the source with a hose or by pumping from the source using a submersible pump (Teel 1P8610). The sample was routed to a 50-gallon air-gap tank (Nalgene) which was outfitted with a float type inlet valve to prevent overflow. The sample was pumped from the air-gap tank through two filters in series using a 1.5 HP pump (ITT Marlow 1½ AP2B) at a maximum rate of 8 gallons per minute. The filters were held in place by polycarbonate cartridge filter holders outfitted with pressure release valves (Teel 1P635A). The first filter in series was a fiber-wound type (K27R10S, Commercial Filter Corp.) which was followed by a Balston Type B cartridge filter (Balston Corp.). Hydrochloric acid and aluminum chloride were metered into the sample at a point between the air gap tank and the pump. The pH was maintained at 3.5 and the aluminum concentration was adjusted to 0.005 M in the effluent samples and 0.0005 M in the well water samples. Sodium sulfite was added, when needed (i.e., chlorinated samples), at a concentration slightly in excess of that necessary to dechlorinate the sample.

Prior to concentration, a grab sample was taken and titrated with 0.1N HCl to determine the amount of acid required to reduce the pH to 3.5. From that point, chemical addition and pH adjustment of the full-scale sample were regulated by an automatic control system, which is diagrammed in Figure C-1. The control system consisted of a flow-through pH cell (Uniloc 320), transmitter (Uniloc 1002), proportional band process controller (Fischer Porter 53EL3311BB1B), current to pressure converter (Robert Shaw 443-B) and a pneumatic valve (Robert Shaw VC-210-BL), which regulated the chemical addition rate.

After pumping the sample through the filters (or after the filter became plugged), the filters were eluted with 1.0 liter of sterile 3.0 percent beef extract (Difco) solution. A reservoir and valving system permitted forward and reverse elutions to be accomplished in a closed loop, thus avoiding potential contamination. Following the reverse elution step, which recovered particulates trapped on the filter surface, the beef extract solution was recovered in a sterile 1.0 liter container and transported to the laboratory for further processing.

FIGURE C-1
SCHEMATIC OF VIRUS CONCENTRATOR



Laboratory Reconcentration

The beef extract eluant was reconcentrated to a final volume of approximately 10 mL by the organic flocculation method (C-4). First, the pH of the 1.0 liter eluant was adjusted to 3.5 with 6N HCl, added dropwise to the side of the beaker and continuously stirred. The resulting precipitate was stirred an additional 30 minutes and then recovered by centrifugation at 15,000 Xg (IEC Model B20 with 872 head) for 15 minutes. The supernatant was discarded and the recovered precipitate was redissolved in 10 mL of 0.15M $NaHPO_4$.

Final concentrates were stored at -75°C prior to assay. Before freezing, 150 units/mL penicillin, 75 µg/mL streptomycin, and 0.75 µg/mL amphotericin B were added to the well water concentrates. Reclaimed water, secondary effluent and primary effluent samples were detoxified with dithizone (C-5). An equal volume of dithizone in chloroform, prepared as described in Standard Methods (C-6), was added to the concentrate, thoroughly mixed for one minute and centrifuged at 40,000 Xg (IEC B20 with 870 head) for 15 minutes. The upper (aqueous) phase of the resulting separation was carefully aspirated and aerated gently for 10 to 15 minutes to remove residual chloroform. Residual dithizone was complexed by addition of 0.05 mL of 0.1 percent $CaCl_2$.

Disinfection of Concentrator

Special disinfection procedures were used for the virus concentrator. The unit was disinfected internally with a muriatic acid solution. The air-gap tank was filled with tap water and the pH was reduced to < 1 with muriatic acid. Acid solution was then pumped through the concentrator. All lines and filter holders were filled with acid solution and the pump was turned off. After a one-hour contact period, the remaining acid solution was pumped through the concentrator and the unit was thoroughly flushed with potable water. Outside surfaces and working areas on the mobile concentrator were disinfected by spraying with Cidex disinfectant. The acid disinfection regimen was experimentally found to be more effective than a 20-30 mg/L chlorine solution held for similar contact times.

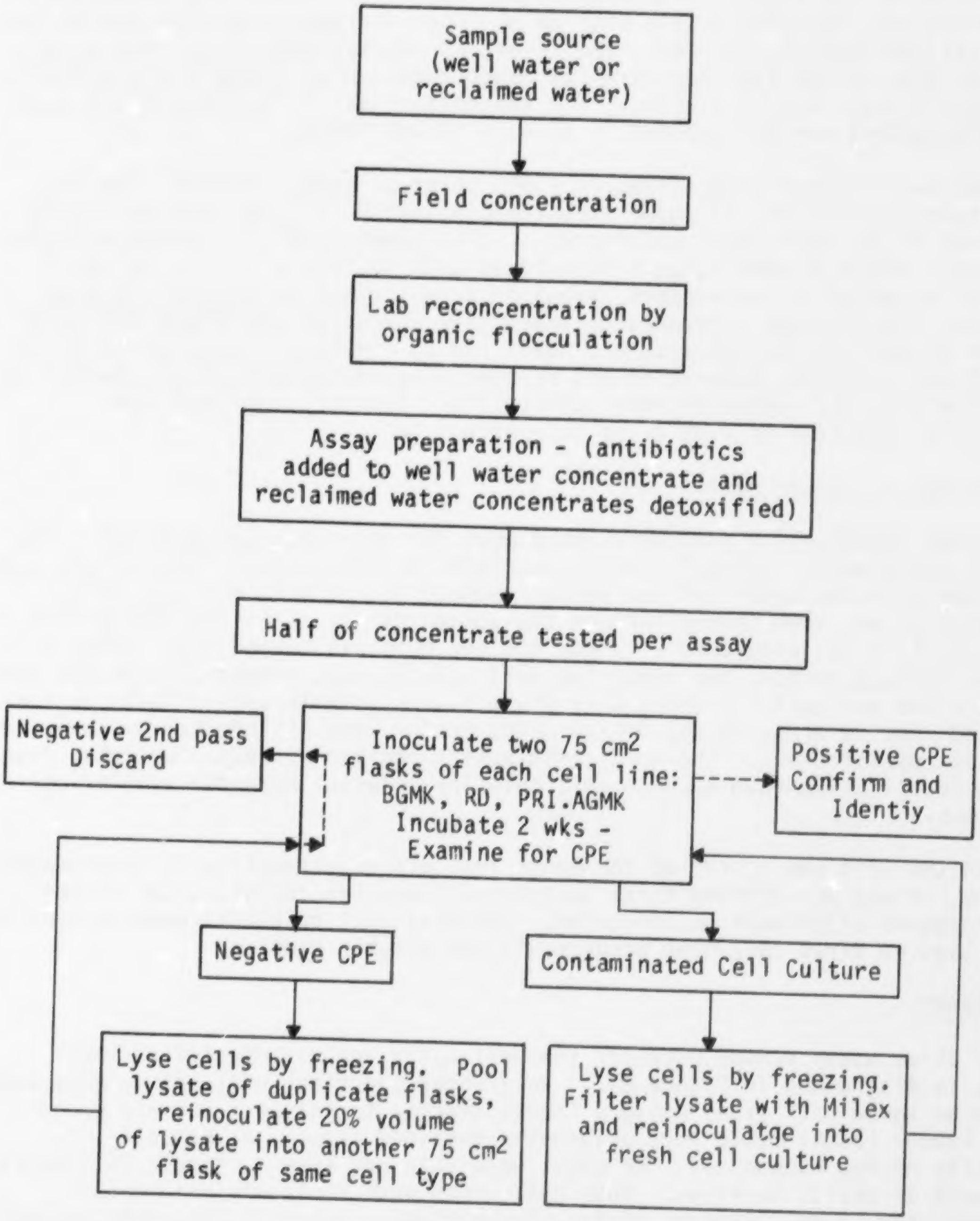
When the unit was scheduled to change from effluent sampling to groundwater sampling, it was disinfected three successive times and potable water blanks were processed after each disinfection. The disinfection blanks were assayed to assure that no virus carryover occurred in the potable samples.

VIRUS ASSAY

The virus assay scheme used for the well water and disinfected effluent samples is diagrammed in Figure C-2. Well water and final effluent samples were assayed on three cell lines using a liquid overlay technique. Buffalo Green Monkey Kidney (BGMK) cells were originally obtained from T. G. Metcalf, University of New Hampshire. RD cells were obtained from J. Riggs, California Department of Health Services. Both cell lines were routinely maintained throughout the Study. Primary African Green Monkey Kidney (PAGMK) cell suspensions were obtained weekly from Flow Laboratories. All cell lines were grown on Eagle Minimum Essential Medium modified with glutamine and Earles' salts (Flow Laboratories). Fetal bovine serum (Flow Laboratories) was added to a final con-

Figure C-2

Flow Diagram for Detection of Virus (a)


Sample source (well water or reclaimed water)
Field concentration
Lab reconcentration by organic flocculation
Assay preparation - (antibiotics added to well water concentrate and reclaimed water concentrates detoxified)
Half of concentrate tested per assay
Negative 2nd pass Discard
Inoculate two 75 cm2 flasks of each cell line: BGMK, RD, PRI.AGMK Incubate 2 wks - Examine for CPE
Positive CPE Confirm and Identiy
Negative CPE
Contaminated Cell Culture
Lyse cells by freezing. Pool lysate of duplicate flasks, reinoculate 20% volume of lysate into another 75 cm2 flask of same cell type
Lyse cells by freezing. Filter lysate with Milex and reinoculatge into fresh cell culture

a. Procedure used for disinfected tertiary effluents and well waters.

centration of 10 percent by volume. BGMK cells were used to passage 150 and then replaced with a lower passage stock. RD cells were received at passage 49 and used through passage 90. Confluent cell monolayers used for assay were grown on disposable 75 cm^2 flasks (Corning).

Each sample concentrate was split and the halves were tested during separate assays. Prior to inoculation, the growth medium was drained from the flasks. The portion of sample being tested was inoculated into duplicate flasks (∿2.5 mL per flask) of the first cell line and given a 2-hour adsorption period. The flasks were rocked back and forth periodically during the adsorption interval. Following the alloted adsorption time, each inoculum was aseptically aspirated from the flask and reinoculated into a drained flask of the second cell line. The adsorption procedure was repeated and then the entire process was repeated for the third cell line. In this manner, all three cell lines were exposed to the entire volume of each sample concentrate.

After the inoculation process was completed, the cells were maintained on Hanks' Maintenance Medium with 5 percent lactalbumin hydrolysate and five percent tryptose (C-7). Penicillin, streptomycin and amphotericin B were added to final concentrations of 150 units/mL, 75 μg/ml and 0.75 μg/mL, respectively. Cells were periodically examined microscopically for cytopathic effect (CPE) for a period of two weeks. Cultures exhibiting CPE were passed to fresh cells for confirmation. Only confirmed positive isolates were slated for identification using a serological pool. Cultures which were negative after the first two weeks were frozen, thawed and the lysate was reinoculated onto fresh cells. These blind passes were again examined for CPE for a period of two weeks. Any assay flasks that became contaminated with either bacteria or fungi during the two-week incubation period were frozen, thawed, and a portion of the lysate was filtered through a sterile 0.22 μm Milex filter (Millipore). The filter-sterilized lysate was reinoculated onto fresh cells.

In addition to the final effluent and well water samples processed, non-disinfected samples of primary, secondary and tertiary effluent were concentrated for evaluation. These samples were assayed by the plaque method on monolayers of BGMK cells grown on 25 cm^2 plastic flasks under Eagle Minimum Essential Medium with 10 percent fetal bovine serum. Plaques counted in samples collected prior to October 1979 were assumed to be of viral origin. After that point, all or a portion of the plaques were picked and confirmed by passage in tube culture.

LARGE VOLUME COLIFORM SAMPLING

For each well site, a 20-liter sample of unchlorinated water was collected in a sterile 5-gallon stainless steel pressure vessel (Cornelius Co.) and transported to the laboratory. The sample was then pressure filtered at 70 psi through a Whatman GF/F filter overlaid with 1.4 g diatomaceous earth (10 mL of 14 g/100 mL diatomaceous earth suspension pressure filtered through GF/F filter). After sample filtration, the GF/F filter and diatomaceous earth layer were aseptically removed and homogenized in 670 mL lauryl sulfate broth (BBL) containing 0.1 percent Tween 80 with a Polytron mixer (Brinkman) operated at low speed. The resulting homogenate was inoculated into multiple tube dilution tests for coliforms. The MPN tests were run as described in Standard Methods (C-6). Final results were expressed as MPN/100 mL of the original sample.

LABORATORY FACILITIES AND OPERATIONAL PROCEDURES

Stringent operational procedures were utilized for all laboratory portions of the virus sampling program. A special virology laboratory was specifically designed for use in the Study. It consisted of two separate laboratories with entry through a common room equipped with sink and washup facilities. One laboratory, used only for potable samples, was designated as the clean room while the other laboratory used for all other sample processing was designated the virology room. The entire laboratory area had its own air conditioning system; filtered air was maintained at a positive pressure in the clean room relative to the rest of the facility. Both rooms were equipped with extensive vertical laminar flow heads providing Class 100 air over work areas.

Access to the clean room was restricted to only those personnel assigned to work in the area. Dedicated laboratory attire was worn in the clean room. Personnel assigned to work in the clean room or with the virus concentrator submitted monthly oral and rectal swabs to screen for sub-clinical enteric virus infections.

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APPENDIX D

RESULTS OF VIRUS SAMPLING - WATER RECLAMATION PLANTS AND WELLS

WASTEWATER SAMPLES

Tables D-1 through D-10 tabulate the virus data collected for the Los Angeles County Sanitation Districts' Pomona (D-1/D-4), San Jose Creek (D-5/D-7), and Whittier Narrows (D-8/D-10) Water Reclamation Plants (WRPs). Tables D-11 and D-12 present the data collected for the Orange County Water District's Water Factory 21. Sampling sites included unchlorinated primary and secondary and chlorinated tertiary effluents for each of the Sanitation Districts' treatment plants; unchlorinated tertiary effluent samples were also collected from the Pomona WRP. Unchlorinated secondary and chlorinated activated carbon/advanced waste treated effluents were sampled at Water Factory 21.

Each table includes the day and date of sampling, coliform results (except for primary effluent samples), chlorine residuals (where appropriate), turbidity, sample volume, and virus results. For those samples with negative results, the calculated detection limit has been shown which represents the minimum number of infective units theoretically detectable in 1,000 gallons of wastewater. A negative isolation indicates that no viruses were detected in the sample using the procedures described in Appendix C. Coliform and chlorine residual data presented in the tables were taken from the treatment plant daily records. Turbidity data for samples collected prior to 2/28/78 were also taken from treatment plants records; subsequent values were derived from grab samples collected at the time of sampling. For each non-disinfected sampling site, the distribution of the virus data and associated probability medians have been shown on probability plots (Figures D-1 through D-8) presented below each corresponding set of tabulated data.

GROUNDWATER SAMPLES

Tables D-13 through D-21 tabulate the virus data collected from the Montebello Forebay wells, while Tables D-22 through D-25 present the data collected for the Anaheim Forebay wells. Each table includes such information as the day and date of sampling, coliform results, chlorine residual (where appropriate), turbidity, sample volume, virus results and detection limit (minimum number of infective units theoretically detectable in 1,000 gallons of water). Coliform and turbidity data were derived from grab samples collected at the time of sampling. Reported chlorine residuals were estimated with an orthotolidine test kit.

TABLE D-1 - VIRUS SAMPLING RESULTS
POMONA WRP PRIMARY EFFLUENT (UNCHLORINATED)

Day and Date		Total Coliform MPN/100 mL (a)	Turbidity FTU	Sample Vol, gal	Virus pfu/1000 gal
Thurs	4-26-79	-	62	30	4.1×10^5
Tues	6-05-79	-	(b)	30	7.8×10^5
Wed	6-06-79	-	(b)	30	1.1×10^6
Thurs	6-07-79	-	(b)	35	1.4×10^6
Fri	7-27-79	-	(b)	30	2.4×10^3
Tues	8-07-79	-	(b)	24	6.0×10^4
Thurs	9-20-79	-	110	40	2.1×10^4
Mon	6-22-81	-	160	25	7.0×10^3
Thurs	6-25-81	-	105	30	9.5×10^5
Mon	6-29-81	-	110	30	9.5×10^5
Wed	7-01-81	-	110	30	3.2×10^6
Tues	8-18-81	-	(b)	35	6.2×10^5
Thurs	9-17-81	-	>100	30	6.1×10^4

(a) - Coliform tests not run for primary effluent.
(b) - Data not available.

FIGURE D-1 PROBABILITY PLOT-VIRUS DATA FOR POMONA WRP UNCHLORINATED PRIMARY EFFLUENT

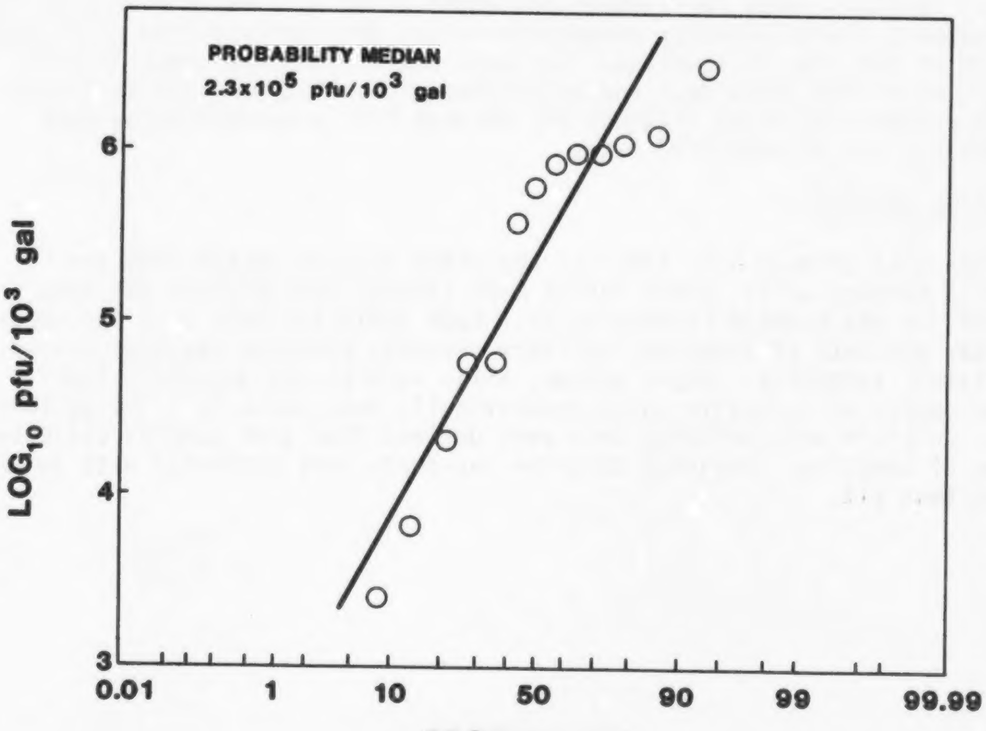

TABLE D-2 - VIRUS SAMPLING RESULTS
POMONA WRP SECONDARY EFFLUENT (UNCHLORINATED)

Day and Date		Total Coliform MPN/100 mL	Turbidity FTU	Sample Vol, gal	Virus pfu/1000 gal
Fri	8-17-79	5.4×10^5	2.7	150	8.5×10^3
Wed	9-19-79	(a)	1.0	100	5.0×10^2
Thurs	6-12-80	(a)	2.7	70	1.5×10^3
Fri	11-21-80	1.1×10^6	4.5	60	7.9×10^3
Wed	4-29-81	7.9×10^5	11.0	100	2.3×10^3
Mon	6-22-81	2.4×10^6	1.4	100	1.3×10^4
Thurs	6-25-81	3.5×10^5	1.4	100	1.2×10^4
Mon	6-29-81	7.9×10^5	1.4	100	1.2×10^4
Wed	7-01-81	1.3×10^5	11.2	100	6.5×10^3
Tues	8-18-81	5.0×10^5	1.4	100	4.8×10^4
Thurs	8-20-81	4.9×10^5	1.0	100	3.4×10^4
Thurs	9-17-81	2.3×10^6	1.2	100	1.8×10^3

(a) Data not available.

FIGURE D-2 PROBABILITY PLOT-VIRUS DATA FOR POMONA WRP UNCHLORINATED SECONDARY EFFLUENT

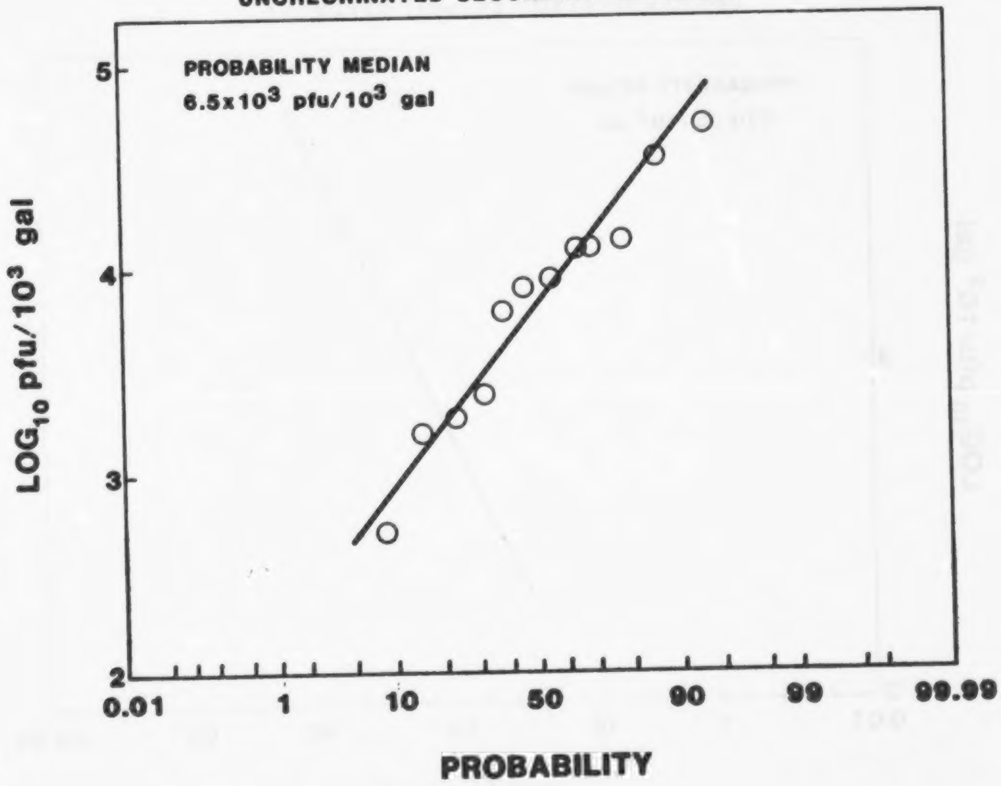

TABLE D-3 - VIRUS SAMPLING RESULTS
POMONA WRP TERTIARY EFFLUENT (UNCHLORINATED)

Day and Date		Total Coliform MPN/100 mL	Turbidity FTU	Sample Vol, gal	Virus pfu/1000 gal
Mon	8-13-79	9.2×10^4	0.38	500	<10
Fri	8-17-79	1.7×10^5	0.30	500	<10
Tues	9-18-79	9.2×10^4	0.30	500	<10
Mon	6-22-81	1.6×10^6	0.42	400	3,600
Thurs	6-25-81	7.9×10^4	0.72	500	2,100
Mon	6-29-81	7.4×10^4	0.64	400	1,400
Wed	7-01-81	1.7×10^5	0.62	500	1,300
Tues	8-18-81	2.0×10^4	0.70	300	<50
Thurs	8-20-81	4.9×10^5	0.40	400	2,500
Thurs	9-17-81	7.0×10^5	0.50	100	<70
Mon	9-28-81	4.6×10^5	1.80	130	<50
Wed	10-07-81	(a)	0.80	200	200

(a) Data not available

FIGURE D-3 PROBABILITY PLOT-VIRUS DATA FOR POMONA WRP UNCHLORINATED TERTIARY EFFLUENT

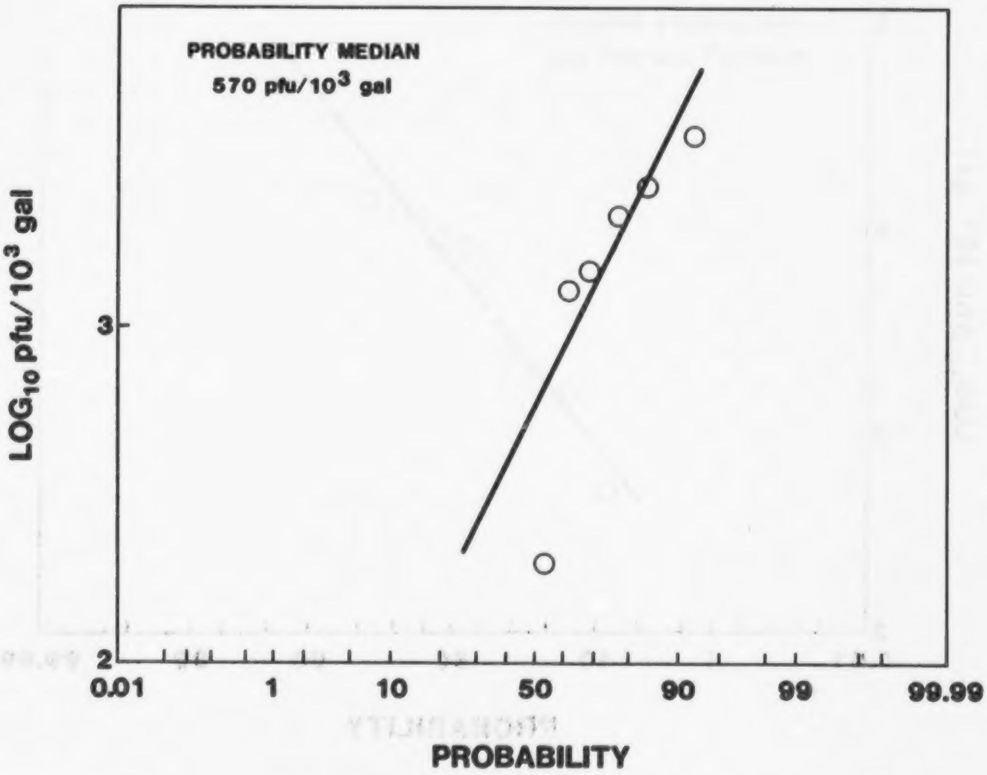

TABLE D-4 - VIRUS SAMPLING RESULTS
POMONA WRP FINAL EFFLUENT

Day and Date	Total Coliform, MPN/100mL Grab Sample	Total Coliform, MPN/100mL 7 Day Median	Chlorine Residual mg/L	Turbidity FTU (a)	Sample Volume gal	Detection Limit I.U./1000 gal	Virus Isolation Results
Wed 1/10/79	<2	<2	5.90	1.4	400	2.5	Neg
Tues 1/16/79	<2	<2	6.50	2.4	300	3	Neg
Mon 1/22/79	<2	<2	5.50	2.3	100	20(c)	Neg
Thurs 2/15/79	<2	<2	4.00	1.3	500	4(c)	Neg
Fri 3/02/79	<2	<2	6.00	0.7	500	2	Neg
Thurs 3/08/79	<2	<2	6.00	1.6	500	2	Neg
Fri 3/30/79	<2	<2	5.75	0.6	400	2.5	Neg
Wed 4/04/79	<2	<2	5.00	0.8	400	2.5	Neg
Tues 4/10/79	<2	<2	5.10	0.5	500	2	Neg
Mon 7/02/79	<2	<2	4.80	1.0	500	2	Neg
Tues 7/10/79	<2	<2	3.30	4.2	200	5	Neg
Thurs 11/15/79	<2	<2	4.00	0.4	500	2	Neg
Wed 1/30/80	<2	<2	4.65	1.3	60	17	Neg
Mon 2/04/80	<2	<2	5.15	1.2	500	2	Neg
Mon 2/25/80	2	<2	4.50	1.0	500	2	Neg
Thurs 4/24/80	<2	<2	3.35	0.7	500	2	Neg
Wed 5/14/80	<2	<2	2.40	0.7	500	2	Neg
Tues 6/10/80	<2	<2	4.00	0.6	500	2	Neg
Tues 7/15/80	<2	<2	4.00	(b)	500	2	Neg
Fri 8/01/80	2	<2	3.50	(b)	500	2	Neg
Mon 9/22/80	<2	<2	3.50	1.2	500	2	Neg
Tues 10/07/80	2	<2	4.00	0.6	500	2	Neg
Fri 11/21/80	<2	<2	3.90	1.0	400	2.5	Neg
Mon 12/01/80	<2	<2	4.90	0.6	500	2	Neg
Tues 1/06/81	2	<2	4.50	2.0	500	2	Neg
Wed 2/25/81	<2	<2	4.00	0.9	500	2	Neg
Thurs 3/19/81	<2	<2	4.90	1.7	300	3	Neg
Wed 4/29/81	<2	<2	4.00	0.8	500	2	Neg
Tues 5/19/81	<2	<2	3.20	0.6	400	2.5	Neg
Thurs 6/11/81	2	<2	3.50	1.2	500	2	Neg
Tues 7/28/81	5	<2	5.60	0.9	500	2	Neg
Tues 8/25/81	<2	<2	8.40	0.9	500	2	Neg
Tues 9/22/81	<2	<2	4.50	0.6	400	2.5	Neg

(a) - Values prior to 2/28/79 are from treatment plant daily records. Subsequent values are from a grab sample collected at time of sampling.
(b) - Data not available.
(c) - Results based on assay of 1/2 of final concentrate due to contamination problems.

TABLE D-5 - VIRUS SAMPLING RESULTS
SAN JOSE CREEK WRP PRIMARY EFFLUENT (UNCHLORINATED)

Day and Date		Total Coliform MPN/100 mL (a)	Turbidity FTU	Sample Vol, gal	Virus pfu/1000 gal
Fri	4-27-79	-	(b)	30	3.9×10^5
Tues	7-21-81	-	~100	25	2.3×10^6
Thurs	7-23-81	-	~110	30	4.3×10^6
Wed	8-05-81	-	~100	25	1.9×10^6
Tues	8-11-81	-	(b)	25	7.2×10^6
Tues	9-01-81	-	100	18	2.0×10^6
Tues	9-15-81	-	100	16	5.0×10^6
Tues	10-13-81	-	(b)	25	1.8×10^5

(a) - Coliform tests not run for primary effluent.

(b) - Data not available.

FIGURE D-4 PROBABILITY PLOT-VIRUS DATA FOR SAN JOSE CREEK WRP UNCHLORINATED PRIMARY EFFLUENT

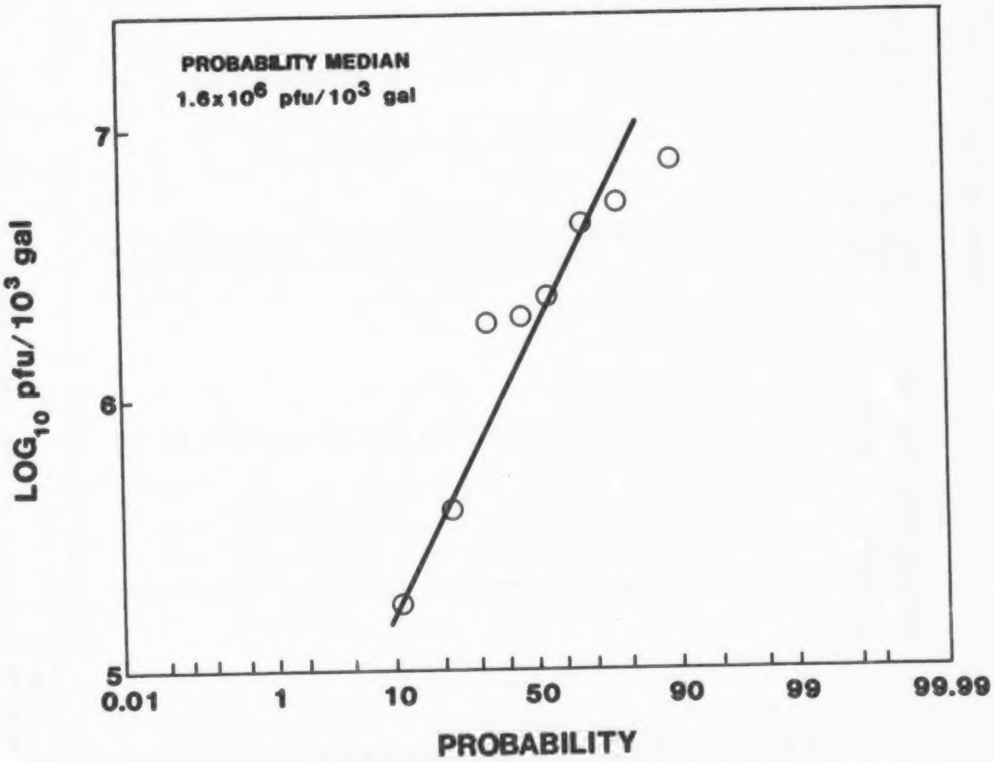

TABLE D-6 - VIRUS SAMPLING RESULTS
SAN JOSE CREEK WRP SECONDARY EFFLUENT (UNCHLORINATED)

Day and Date		Total Coliform MPN/100 mL	Turbidity FTU	Sample Vol, gal	Virus pfu/1000 gal
Tues	4-24-79	2.4×10^6	2.5	100	100
Wed	8-15-79	1.6×10^6	1.4	200	790
Mon	12-31-79	1.7×10^6	3.2	68	180
Thurs	7-17-80	1.7×10^7	3.3	100	14,000
Wed	10-08-80	7.9×10^5	2.5	200	<100
Wed	12-03-80	1.7×10^6	1.7	100	180
Mon	3-23-81	2.4×10^9	1.7	100	1,600
Thurs	5-21-81	$\geq 2.4 \times 10^6$	1.7	100	5,700
Tues	7-21-81	5.4×10^6	4.5	100	2,600
Thurs	7-23-81	1.1×10^6	1.9	100	2,300
Wed	8-05-81	7.0×10^5	3.8	100	<100
Tues	8-11-81	1.3×10^6	6.6	70	600
Tues	9-01-81	3.5×10^6	1.3	100	13,000
Tues	9-15-81	4.9×10^7	3.9	50	<240

FIGURE D-5 PROBABILITY PLOT-VIRUS DATA FOR SAN JOSE CREEK WRP UNCHLORINATED SECONDARY EFFLUENT

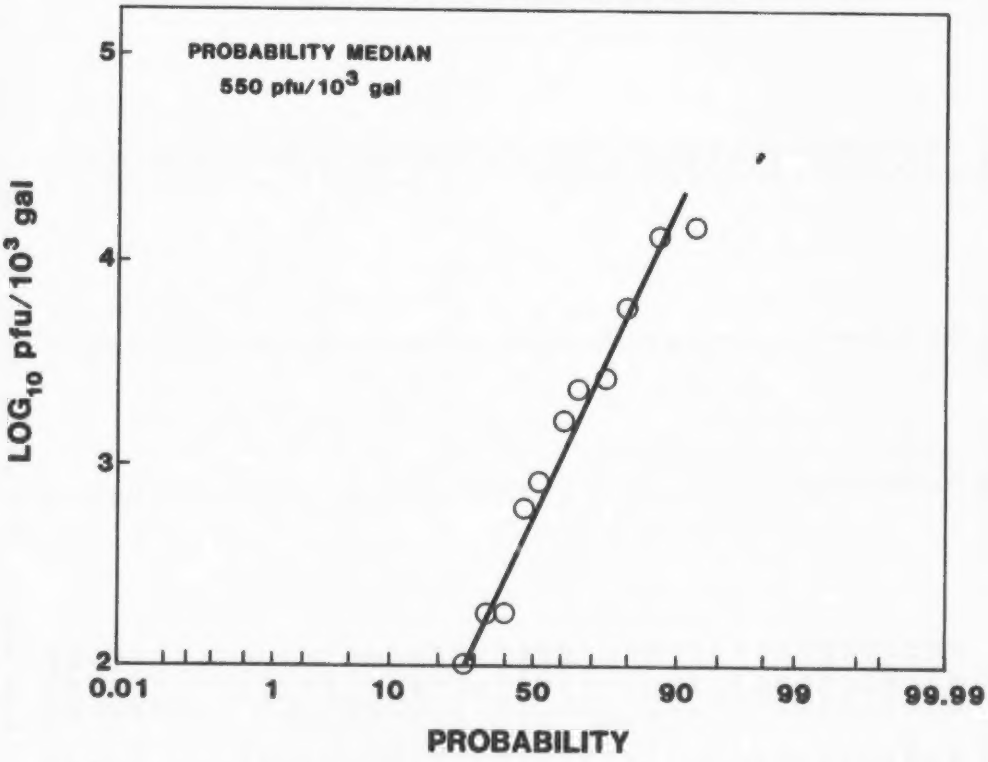

TABLE D-7 - VIRUS SAMPLING RESULTS
SAN JOSE CREEK WRP FINAL EFFLUENT

Day and Date		Total Coliform, MPN/100mL Grab Sample	Total Coliform, MPN/100mL 7 Day Median	Chlorine Residual mg/L	Turbidity FTU (a)	Sample Volume gal	Detection Limit I.U./1000 gal	Virus Isolation Results
Tues	1/09/79	2	2	4.50	2.4	220	4.5	Neg
Wed	1/17/79	<2	5	3.60	2.2	300	6(c)	Neg
Thurs	2/01/79	9	2	2.15	3.7	200	10(c)	Neg
Mon	2/05/79	2	2	4.15	2.3	300	6(c)	Neg
Fri	2/23/79	<2	<2	5.55	3.5	300	6(c)	Neg
Mon	3/05/79	<2	2	3.20	4.0	100	10	Neg
Wed	3/07/79	13	2	5.55	1.6	350	3	Neg
Thur	3/22/79	2	2	4.80	1.6	250	4	Neg
Mon	4/02/79	2	<2	6.90	1.1	200	5	Neg
Tues	7/03/79	2	<2	4.05	0.7	500	2	Neg
Fri	7/06/79	2	<2	5.20	0.7	500	2	Neg
Thurs	7/12/79	2	2	5.30	0.7	500	2	Neg
Wed	8/29/79	<2	<2	4.95	1.4	500	2	Neg
Wed	9/05/79	<2	<2	3.50	1.3	475	2	Neg
Thurs	10/11/79	<2	<2	3.00	1.7	500	2	Neg
Tues	11/06/79	<2	2	5.75	2.2	400	2.5	Neg
Wed	12/12/79	2	2	5.00	2.0	500	2	Neg
Thurs	1/24/80	2	2	8.00	1.4	250	4	Neg
Tues	2/05/80	<2	<2	11.90	2.5	250	4	Neg
Tues	2/26/80	2	2	6.75	8.5	100	10	Neg
Thurs	2/28/80	8	2	5.50	2.7	180	6	Neg
Tues	3/04/80	2	2	4.00	5.2	120	8	Neg
Wed	3/05/80	<2	<2	4.35	3.2	175	6	Neg
Fri	4/25/80	8	<2	6.50	2.1	500	2	Neg
Thurs	5/15/80	<2	<2	7.00	(b)	400	2.5	Neg
Mon	6/09/80	<2	<2	7.15	1.2	400	2.5	Neg
Thurs	7/17/80	<2	<2	4.35	1.8	180	6	Neg
Mon	8/04/80	<2	<2	4.50	6.0	100	10	Neg
Wed	9/17/80	<2	<2	4.75	1.3	500	2	Neg
Wed	10/08/80	2	<2	4.75	1.5	40	25	Neg
Wed	11/19/80	<2	<2	(b)	1.2	400	2.5	Neg
Wed	12/03/80	<2	<2	3.95	1.6	300	3.3	Neg
Wed	1/07/81	<2	<2	6.50	1.6	500	2	Neg
Thurs	2/19/81	7	2	8.65	1.7	300	3	Neg
Fri	2/20/81	<2	<2	8.55	1.6	300	3	Neg
Mon	2/23/81	<2	<2	9.00	1.6	300	3	Neg
Mon	3/23/81	<2	<2	8.50	1.3	300	3	Neg
Mon	4/27/81	2	<2	6.15	1.3	400	2.5	Neg
Thurs	5/21/81	<2	<2	8.75	1.3	400	2.5	Neg
Mon	6/15/81	<2	<2	5.90	1.3	400	2.5	Neg
Wed	7/29/81	<2	<2	4.90	1.2	400	2.5	Neg
Wed	8/26/81	<2	<2	4.15	1.3	400	2.5	Neg
Mon	10/05/81	<2	<2	6.00	1.8	300	3	Neg

(a) - Values prior to 2/28/79 are from treatment plant daily records. Subsequent values are from a grab sample collected at time of sampling.

(b) - Data not available.

(c) - Results based on assay of 1/2 of final concentrate due to contamination problems.

TABLE D-8 - VIRUS SAMPLING RESULTS
WHITTIER NARROWS WRP PRIMARY EFFLUENT (UNCHLORINATED)

Day and Date	Total Coliform MPN/100 mL (a)	Turbidity FTU	Sample Vol, gal	Virus pfu/1000 gal
Tues 7-07-81	-	50	25	1.6 X 10^6
Thurs 7-09-81	-	36	25	1.9 X 10^6
Mon 8-03-81	-	~100	30	4.0 X 10^6
Thurs 8-13-81	-	>100	35	2.2 X 10^6
Thurs 9-03-81	-	>100	29	4.0 X 10^6
Thurs 9-09-81	-	>100	29	4.0 X 10^4
Tues 9-29-81	-	>100	20	2.1 X 10^5
Wed 10-14-81	-	(a)	25	1.4 X 10^5

(a) - Coliform tests not run for primary effluent.
(b) - Data not available.

FIGURE D-6 PROBABILITY PLOT-VIRUS DATA FOR WHITTIER NARROWS WRP UNCHLORINATED PRIMARY EFFLUENT

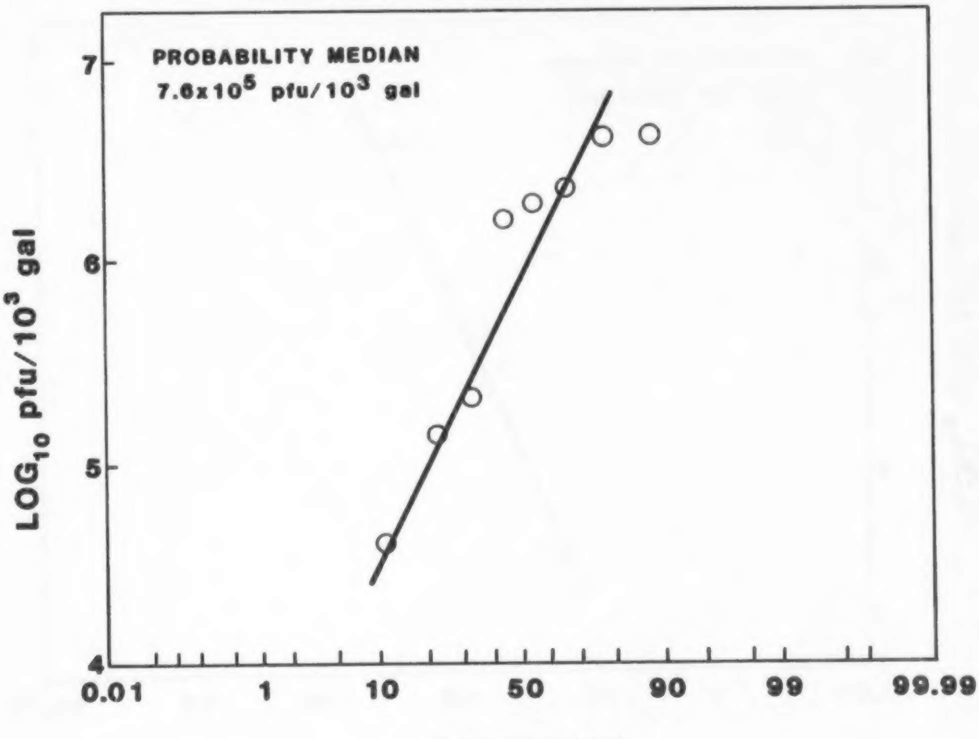

TABLE D-9 - VIRUS SAMPLING RESULTS
WHITTIER NARROWS WRP SECONDARY EFFLUENT (UNCHLORINATED)

Day and Date		Total Coliform MPN/100 mL	Turbidity FTU	Sample Vol, gal	Virus pfu/1000 gal
Thurs	8-23-79	3.3×10^5	(a)	80	330
Wed	8-06-80	(a)	1.8	185	520
Tues	7-07-81	1.1×10^6	2.0	100	4,400
Thurs	7-09-81	3.3×10^5	1.8	100	5,600
Mon	8-03-81	2.8×10^5	3.3	100	4,400
Thurs	8-13-81	7.9×10^5	1.6	100	40
Thurs	9-03-81	7.0×10^4	>100	30	5,300
Wed	9-09-81	2.3×10^5	2.2	100	<120
Tues	9-29-81	4.6×10^5	2.2	30	500

(a) Data not available.

FIGURE D-7 PROBABILITY PLOT-VIRUS DATA FOR WHITTIER NARROWS WRP UNCHLORINATED SECONDARY EFFLUENT

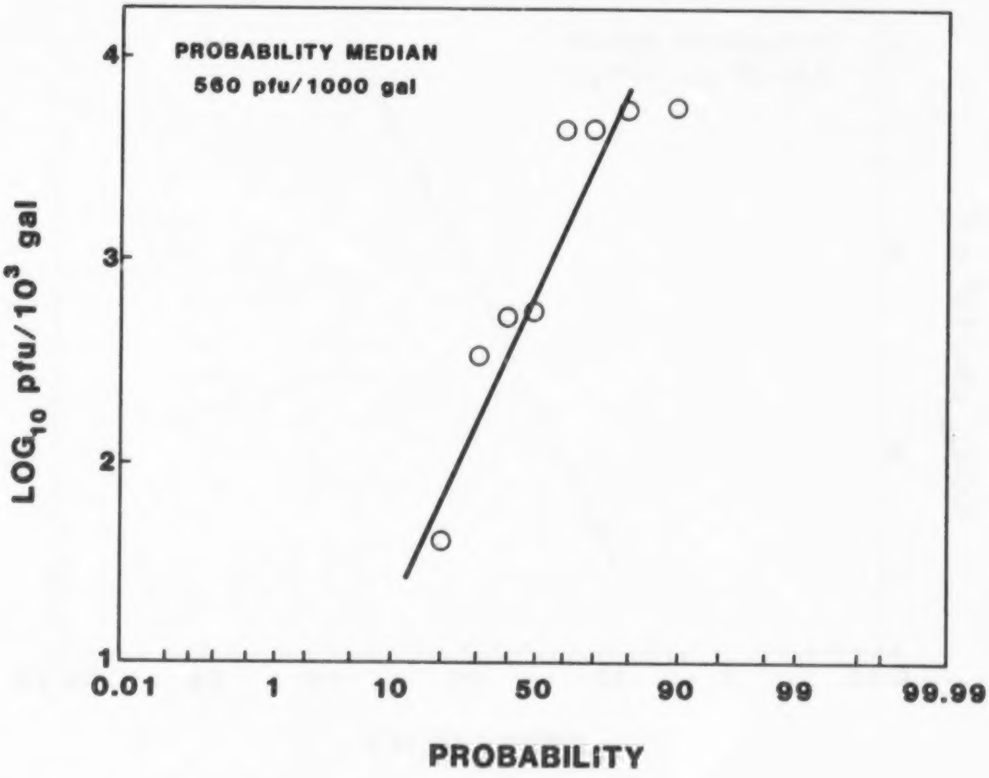

TABLE D-10 - VIRUS SAMPLING RESULTS
WHITTIER NARROWS WRP FINAL EFFLUENT

Day and Date		Total Coliform, MPN/100mL Grab Sample	Total Coliform, MPN/100mL 7 Day Median	Chlorine Residual mg/L	Turbidity FTU (a)	Sample Volume gal	Detection Limit I.U./1000 gal	Virus Isolation Results
Thurs	1/11/79	<2	5	5.00	1.2	125	8	Neg
Fri	1/19/79	<2	<2	4.50	1.7	250	8(b)	Neg
Mon	1/29/79	<2	<2	8.50	2.0	350	3	Neg
Tues	2/06/79	<2	<2	5.10	1.8	420	4(b)	Neg
Wed	2/21/79	<2	<2	6.50	1.3	500	4(b)	Neg
Fri	3/09/79	5	<2	5.50	2.8	250	4	Neg
Thurs	3/29/79	2	<2	6.10	0.3	500	2	Neg
Tues	4/03/79	2	2	6.50	0.5	500	2	Neg
Wed	6/27/79	<2	<2	7.30	1.0	500	2	Neg
Mon	7/09/79	<2	<2	9.00	0.3	500	2	Neg
Wed	7/11/79	5	<2	5.00	1.0	500	2	Neg
Tues	8/28/79	<2	<2	3.50	1.0	300	3	Neg
Thurs	9/06/79	5	2	5.70	0.9	300	3	Neg
Wed	10/10/79	<2	<2	5.30	1.4	400	2.5	Neg
Fri	10/12/79	<2	<2	5.45	1.3	300	3	Neg
Wed	10/17/79	<2	<2	4.50	1.2	300	3	Neg
Tues	11/13/79	<2	<2	4.20	1.3	400	2.5	Neg
Tues	12/18/79	2	2	6.70	1.0	500	2	Neg
Fri	1/25/80	<2	2	7.20	1.2	410	2	Neg
Wed	2/06/80	<2	<2	5.50	1.3	250	4	Neg
Wed	2/27/80	<2	2	5.50	1.0	300	3	Neg
Wed	4/23/80	<2	<2	6.70	1.2	400	2.5	Neg
Tues	5/13/80	<2	<2	7.50	1.2	500	2	Neg
Mon	7/14/80	<2	<2	5.00	0.9	500	2	Neg
Tues	8/05/80	<2	<2	4.65	0.9	350	3	Neg
Wed	9/24/80	<2	<2	5.00	1.2	500	2	Neg
Mon	10/06/80	<2	<2	5.20	0.7	400	2.5	Neg
Thurs	11/20/80	<2	<2	6.30	1.2	400	2.5	Neg
Tues	12/02/80	<2	2	5.30	1.2	400	2.5	Neg
Mon	1/05/81	<2	<2	5.80	1.2	400	2.5	Neg
Tues	2/24/81	13	<2	4.50	1.9	300	3	Neg
Fri	3/20/81	<2	<2	8.70	1.7	500	2	Neg
Tues	4/28/81	<2	<2	5.50	2.0	150	7	Neg
Wed	5/20/81	2	2	5.30	1.2	300	3	Neg
Tues	6/16/81	<2	<2	5.00	1.3	300	3	Neg
Fri	7/03/81	<2	<2	5.50	0.8	200	5	Neg
Fri	8/28/81	<2	<2	4.75	1.6	400	2.5	Neg
Thurs	9/24/81	<2	<2	6.00	0.8	400	2.5	Neg

(a) - Values prior to 2/28/79 are from treatment plant daily records. Subsequent values are from a grab sample collected at time of sampling.

(b) - Data not available.

(c) - Results based on assay of 1/2 of final concentrate due to contamination problems.

TABLE D-11 - VIRUS SAMPLING RESULTS
WATER FACTORY 21 INFLUENT (a)

Day and Date	Total Coliform MPN/100 mL	Turbidity FTU	Sample Vol, gal	Virus pfu/1000 gal
Tues 1-23-79	$\geq 2.4 \times 10^3$	15	90	600
Tues 1-30-79	1.1×10^5	9.8	100	210
Tues 2-13-79	9.2×10^5	14.4	100	40
Fri 2-16-79	$\geq 2.4 \times 10^6$	(b)	100	1,200
Wed 2-28-79	1.1×10^7	18.9	100	900
Mon 3-26-79	7.9×10^5	13	100	2,300
Thurs 4-05-79	4.9×10^4	3.5	100	210
Thurs 9-27-79	2.3×10^5	3.4	40	(b)
Wed 10-03-79	3.3×10^5	4.4	100	910
Fri 10-05-79	1.3×10^7	2.5	70	60
Thurs 10-18-79	7.9×10^4	1.8	100	320

(a) - Sampling point designated Q1, unchlorinated secondary effluent.
(b) - Data not available.

FIGURE D-8 PROBABILITY PLOT-VIRUS DATA FOR WATER FACTORY 21 INFLUENT

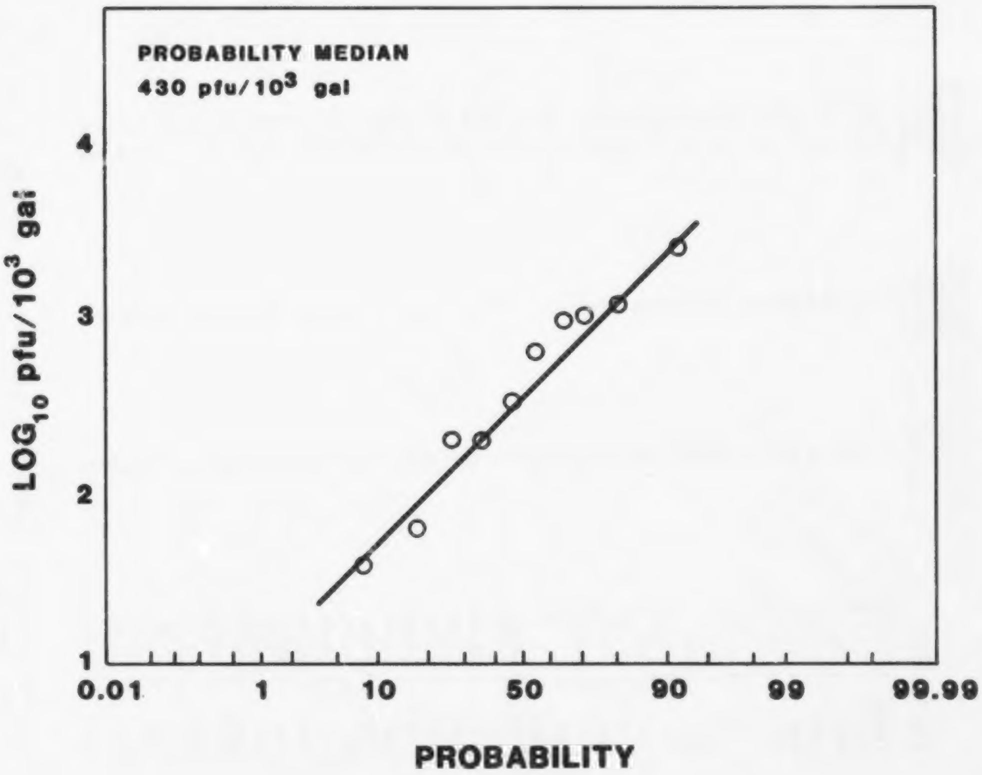

TABLE D-12 VIRUS SAMPLING RESULTS
WATER FACTORY 21 - Q9 EFFLUENT (a)

Day and Date	Total Coliform MPN/100 mL	Chlorine Residual mg/L	Turbidity FTU	Sample Volume gal	Detection Limit I.U./1000 gal	Virus Isolation Results
Tues 1-30-79	<2	(b)	(b)	885	1	Neg
Tues 2-13-79	<2	0.64	(b)	1000	2(c)	Neg
Fri 2-16-79	<2	(b)	(b)	1000	2(c)	Neg
Wed 2-28-79	<2	(b)	(b)	1000	1	Neg
Mon 3-26-79	<2	3.9	0.3	900	1	Neg
Thurs 4-05-79	<2	(b)	0.26	1000	1	Neg
Thurs 9-27-79	<2	(b)	0.3	1000	1	Neg
Wed 10-03-79	<2	(b)	<0.2	1000	1	Neg
Fri 10-05-79	<2	(b)	0.2	1000	1	Neg
Thurs 10-18-79	<2	(b)	0.2	1000	1	Neg

(a) - Chlorinated activated carbon effluent.

(b) - Data not available.

(c) - Results based on assay of 1/2 of final concentrate due to contamination problems.

TABLE D-13 VIRUS SAMPLING RESULTS
WELL 1514A - CITY OF SOUTH GATE

Day and Date		Total Coliform MPN/100 mL	Chlorine Residual mg/L	Turbidity FTU	Sample Volume gal	Detection Limit I.U./1000 gal	Virus Isolation Results
Wed	4-09-80	<2	NA(a)	0.07	1000	1	Neg
Mon	4-21-80	<2	NA	0.15	1000	1	Neg
Thurs	5-08-80	2	NA	0.06	1000	1	Neg
Tues	6-03-80	<3(b)	NA	0.14	1000	1	Neg
Wed	7-02-80	<2	NA	0.09	1000	1	Neg
Tues	7-22-80	<2	NA	0.14	1000	1	Neg
Wed	10-01-80	<2	NA	0.09	1000	1	Neg
Mon	12-08-80	<2	NA	0.06	1000	1	Neg
Wed	2-04-81	<2	NA	0.06	1000	1	Neg
Tues	4-14-81	5	NA	0.08	1000	1	Neg

(a) - NA = Not applicable, unchlorinated well.
(b) - Value from 3 tube MPN test.

TABLE D-14 VIRUS SAMPLING RESULTS
WELL 1562E - PARK WATER CO.

Day and Date		Total Coliform MPN/100 mL	Chlorine Residual mg/L	Turbidity FTU	Sample Volume gal	Detection Limit I.U./1000 gal	Virus Isolation Results
Tues	4-08-80	<2	0.1(a)	2.5	465	2	Neg
Mon	5-05-80	<2	NA (b)	0.8	1000	1	Neg
Thurs	5-29-80	<3(c)	NA	7.9	1000	1	Neg
Wed	6-18-80	<2	NA	7.8	1000	1	Neg
Wed	7-09-80	<2	NA	27	1000	1	Neg
Wed	9-10-80	<2	NA	11	1000	1	Neg
Wed	11-26-80	<2	NA	9.2	1000	1	Neg
Tues	1-13-81	<2	<0.5(a)	9.2	1000	1	Neg

(a) - Chlorinator at well site in operation.
(b) - NA = not applicable, chlorinator not in operation.
(c) - Value from 3 tube MPN test.

TABLE D-15 VIRUS SAMPLING RESULTS
WELL 1566A - CITY OF DOWNEY

Day and Date		Total Coliform MPN/100 mL	Chlorine Residual mg/L	Turbidity FTU	Sample Volume gal	Detection Limit I.U./1000 gal	Virus Isolation Results
Mon	3-31-80	<2	NA(a)	0.06	1000	1	Neg
Tues	4-15-80	<2	NA	0.11	1000	1	Neg
Wed	5-07-80	2	NA	0.05	1000	1	Neg
Fri	5-23-80	(b)	NA	0.06	1000	1	Neg
Fri	6-20-80	<2	NA	0.23	1000	1	Neg
Thurs	7-10-80	<2	NA	0.08	1000	1	Neg
Tues	10-28-80	<2	NA	0.04	1000	1	Neg
Fri	11-07-80	<2	NA	0.06	1000	1	Neg
Mon	1-12-81	(b)	NA	0.11	1000	1	Neg
Tues	2-03-81	<2	NA	0.06	1000	1	Neg
Fri	5-08-81	<2	NA	0.51	1000	1	Neg

(a) - NA = not applicable, unchlorinated well.
(b) - Data not available.

TABLE D-16 VIRUS SAMPLING RESULTS
WELL 1580J - SOUTH MONTEBELLO IRRIGATION DISTRICT

Day and Date		Total Coliform MPN/100 mL	Chlorine Residual mg/L	Turbidity FTU	Sample Volume gal	Detection Limit I.U./1000 gal	Virus Isolation Results
Fri	4-11-80	<2	NA(a)	0.07	1000	1	Neg
Fri	5-02-80	<2	NA	0.08	1000	1	Neg
Wed	5-28-80	3(b)	NA	0.07	1000	1	Neg
Thurs	6-19-80	<2	NA	0.10	1000	1	Neg
Mon	7-07-80	<2	NA	0.10	1000	1	Neg
Fri	7-25-80	<2	NA	0.10	1000	1	Neg
Tues	9-09-80	<2	NA	0.10	1000	1	Neg
Fri	11-14-80	<2	NA	0.06	1000	1	Neg
Wed	1-14-81	<2	NA	0.07	1000	1	Neg
Wed	2-11-81	8	NA	0.09	1000	1	Neg
Wed	5-13-81	28	NA	0.18	1000	1	Neg

(a) - NA = Not applicable, unchlorinated well.
(b) - Value from 3 tube MPN test.

TABLE D-17 VIRUS SAMPLING RESULTS
WELL 1591H - CITY OF PICO RIVERA

Day and Date	Total Coliform MPN/100 mL	Chlorine Residual mg/L	Turbidity FTU	Sample Volume gal	Detection Limit I.U./1000 gal	Virus Isolation Results
Mon 4-07-80	<2	NA(a)	0.14	450	2	Neg
Thurs 6-26-80	<2	NA	0.18	1000	1	Neg
Tues 7-29-80	(b)	NA	0.14	1000	1	Neg
Wed 9-03-80	<2	NA	0.16	1000	1	Neg
Thurs 12-18-80	<2	NA	(b)	900	1	Neg
Mon 12-29-80	<2	NA	0.11	600	1.7	Neg
Fri 1-30-81	<2	NA	0.13	260	4	Neg
Thurs 3-12-81	<2	NA	0.06	1000	1	Neg
Thurs 4-16-81	<2	NA	0.60	1000	1	Neg
Wed 5-27-81	8	NA	1.60	1000	1	Neg

(a) - NA = Not applicable, unchlorinated well.
(b) - Data not available.

TABLE D-18 VIRUS SAMPLING RESULTS
WELL 1620GG - SAN GABRIEL VALLEY WATER CO.

Day and Date	Total Coliform MPN/100 mL	Chlorine Residual mg/L	Turbidity FTU	Sample Volume gal	Detection Limit I.U./1000 gal	Virus Isolation Results
Mon 4-14-80	<2	NA	0.13	1000	1	Neg
Thurs 5-01-80	<2	NA	0.12	1000	1	Neg
Thurs 5-22-80	3	NA	0.07	1000	1	Neg
Tues 7-01-80	<2	NA	0.08	1000	1	Neg
Thurs 7-24-80	<2	NA	0.12	1000	1	Neg
Tues 9-02-80	<2	NA	0.09	1000	1	Neg
Mon 11-10-80	<2	NA	0.07	1000	1	Neg
Tues 12-23-80	8	NA	0.06	1000	1	Neg
Wed 5-06-81	>77	NA	0.20	1000	1	Neg
Fri 5-29-81	<2	NA	0.07	1000	1	Neg

(a) - NA = Not applicable, unchlorinated well.

TABLE D-19 VIRUS SAMPLING RESULTS
WELL 2907 - CITY OF MONTEBELLO

Day and Date	Total Coliform MPN/100 mL	Chlorine Residual mg/L	Turbidity FTU	Sample Volume gal	Detection Limit I.U./1000 gal	Virus Isolation Results
Thurs 4-03-80	<2	3	0.21	1000	1	Neg
Wed 4-16-80	<2	3	0.24	1000	1	Neg
Tues 5-06-80	<2	3	0.21	1000	1	Neg
Mon 6-23-80	<2	1	0.33	1000	1	Neg
Tues 7-08-80	<2	2	0.27	1000	1	Neg
Thurs 7-31-80	<2	3	0.27	1000	1	Neg
Tues 9-16-80	<2	0.5	0.26	1000	1	Neg
Mon 12-15-80	<2	3	0.19	1000	1	Neg
Mon 2-02-81	<2	1.5	0.19	1000	1	Neg
Fri 4-10-81	<2	3	(a)	1000	1	Neg

(a) - Data not available.

TABLE D-20 VIRUS SAMPLING RESULTS
WELL 2947Q - CITY OF WHITTIER

Day and Date	Total Coliform MPN/100 mL	Chlorine Residual mg/L	Turbidity FTU	Sample Volume gal	Detection Limit I.U./1000 gal	Virus Isolation Results
Wed 4-02-80	<2	NA(a)	0.25	1000	1	Neg
Thurs 4-17-80	<2	NA	0.11	1000	1	Neg
Wed 5-21-80	3	NA	0.13	1000	1	Neg
Thurs 6-05-80	<2	NA	0.09	1000	1	Neg
Wed 6-25-80	<2	NA	0.19	1000	1	Neg
Mon 7-21-80	49	NA	0.15	1000	1	Neg
Fri 12-19-80	(b)	NA	0.13	1000	1	Neg
Wed 1-21-81	<2	NA	0.27	1000	1	Neg
Wed 2-18-81	(b)	NA	0.55	1000	1	Neg
Wed 4-22-81	<2	NA	0.18	1000	1	Neg

(a) - NA = Not applicable, unchlorinated well.
(b) - Data not available.

TABLE D-21 VIRUS SAMPLING RESULTS
WELL 2958A - BEVERLY ACRES ESTATES

Day and Date		Total Coliform MPN/100 ml	Chlorine Residual mg/L	Turbidity FTU	Sample Volume gal	Detection Limit I.U./1000 gal	Virus Isolation Results
Mon	5-12-80	2	1	0.06	1000	1	Neg
Tues	6-24-80	<2	<0.5	0.13	1000	1	Neg
Mon	6-30-80	<2	<0.5	0.14	1000	1	Neg
Wed	7-30-80	<2	<1	0.15	1000	1	Neg
Mon	10-20-80	4	0.5	0.14	1000	1	Neg
Tues	12-09-80	<2	0.5	0.08	1000	1	Neg
Tues	12-30-80	<2	2	0.05	1000	1	Neg
Mon	1-19-81	<2	(a)	0.13	1000	1	Neg
Tues	3-17-81	<2	1	0.06	1000	1	Neg
Mon	4-20-81	<2	1	0.10	1000	1	Neg

(a) - Data not available.

TABLE D-22 VIRUS SAMPLING RESULTS
WELL 22 - CITY OF ANAHEIM

Day and Date		Total Coliform MPN/100 mL	Chlorine Residual mg/L	Turbidity FTU	Sample Volume gal	Detection Limit I.U./1000 gal	Virus Isolation Results
Tues	8-12-80	23	NA(a)	0.10	1000	1	Neg
Mon	9-15-80	<2	NA	0.08	1000	1	Neg
Mon	11-17-80	<2	NA	0.13	1000	1	Neg
Fri	1-06-81	<2	NA	0.13	1000	1	Neg
Wed	4-01-81	<2	NA	0.10	1000	1	Neg

(a) - NA = Not applicable, unchlorinated well.

TABLE D-23 VIRUS SAMPLING RESULTS
WELL 27 - CITY OF ANAHEIM

Day and Date	Total Coliform MPN/100 mL	Chlorine Residual mg/L	Turbidity FTU	Sample Volume gal	Detection Limit I.U./1000 gal	Virus Isolation Results
Mon 8-11-80	<2	NA(a)	0.15	1000	1	Neg
Mon 9-08-80	<2	NA	0.08	1000	1	Neg
Tues 11-18-80	<2	NA	0.23	1000	1	Neg
Thurs 1-05-81	<2	NA	0.34	1000	1	Neg
Tues 4-07-81	<2	NA	0.12	1000	1	Neg

(a) - NA = Not applicable, unchlorinated well.

TABLE D-24 VIRUS SAMPLING RESULTS
WELL 29 - CITY OF ANAHEIM

Day and Date	Total Coliform MPN/100 mL	Chlorine Residual mg/L	Turbidity FTU	Sample Volume gal	Detection Limit I.U./1000 gal	Virus Isolation Results
Wed 8-13-80	<2	NA(a)	0.06	1000	1	Neg
Tues 10-21-80	2	NA	0.08	1000	1	Neg
Thurs 12-11-80	<2	NA	0.08	1000	1	Neg
Tues 3-10-81	<2	NA	0.06	1000	1	Neg
Mon 3-30-81	<2	NA	0.30	1000		Neg

(a) - NA = Not applicable, unchlorinated well.

TABLE D-25 VIRUS SAMPLING RESULTS
WELL 11 - CITY OF YORBA LINDA

Day and Date	Total Coliform MPN/100 mL	Chlorine Residual mg/L	Turbidity FTU	Sample Volume gal	Detection Limit I.U./1000 gal	Virus Isolation Results
Thurs 8-14-80	<2	1	0.12	1000	1	Neg
Fri 12-12-80	<2	1	0.13	1000	1	Neg
Tues 2-10-81	<2	<0.5	0.46	1000	1	Neg
Tues 6-02-81	<2	(a)	2.20	600	1.7	Neg
Tues 6-09-81	5	(a)	0.30	1000	1	Neg

(a) - Data not available.

APPENDIX E

CONCENTRATION, FRACTIONATION, AND DERIVATIZATION METHODS FOR NON-PURGEABLE ORGANIC RESIDUES

SUMMARY

These procedures are applicable to the isolation of organic species from ground, surface and reclaimed water. The concentrator apparatus consists of a diaphragm or piston pump and a series of stainless steel columns packed with 45-75 m polymeric styrene-divinylbenzene or acrylic ester resin particles of the ion-exchange and nonionic varieties. The small-particle resins are wet sieved to ensure size uniformity, poured into the columns, and washed with various solvents until background contamination is reduced to low levels. A pre-filtered water sample is pumped through the series of columns. The final few liters of concentrator effluent are saved for later evaluation, if warranted. After the sample has passed through the concentrator, acetonitrile is pumped in reverse direction through the individual columns. The acetonitrile effluents are combined with acetonitrile washings from the prefilter and saturated with NaCl to separate excess water. The aqueous effluents are adjusted to the desired pH, saturated with NaCl and extracted with acetonitrile. The organic portions are evaporated in Kuderna-Danish apparatus, removing all water as the azeotrope with acetonitrile. Residues are further evaporated with micro-Snyder apparatus and stored at -20°C until tested. Portions of composite residues for each sample may be fractionated by HPLC for Ames testing and GC/MS analysis.

Experiments have shown that, on the average, recovery of organic carbon of 70 percent may be expected; recoveries of hydrophobic organic compounds from drinking water and reclaimed water also averaged 70 percent.

OUTLINE FOR DESCRIPTION OF CONCENTRATION METHODS

Apparatus

1. Prototype concentrator
2. High-volume concentrator
3. Grinding and sieving
4. Sample collection
5. Solvent evaporation
6. Fractionation

Procedures

1. Column preparation
    - 1.1 Columns and fittings
    - 1.2 Grinding resins
    - 1.3 Sieving resins

1.3.1 MP-1 and MP-50
1.3.2 XAD-7
1.3.3 XAD-2

1.4 Slurry packing

1.5 Resin purification

1.5.1 MP-1
1.5.2 MP-50
1.5.3 XAD-2
1.5.4 XAD-7

2. Sampling

2.1 Preparation of equipment

2.1.1 Filter
2.1.2 Glass bottles - TOC and VOA
2.1.3 Glass bottles - coliform
2.1.4 Glass bottles - water quality and trace organic analysis
2.1.5 Stainless steel drum - trace organic analysis

2.2 Sample collection

3. Trace organic isolation

3.1 Columns
3.2 Adsorption
3.3 Elution

3.3.1 Reagents
3.3.2 Filter
3.3.3 MP-1 column(s)
3.3.4 MP-50 column
3.3.5 XAD-2 and XAD-7 columns

3.4 Extraction

3.4.1 Acetonitrile effluents
3.4.2 Aqueous effluents
3.4.3 Influent and effluent water

3.5 Evaporation

3.5.1 Kuderna-Danish
3.5.2 Micro-Synder
3.5.3 Air-vacuum

4. Fractionation

4.1 Reverse phase - step gradient

        4.1.1 Analytical scale
        4.1.2 Preparative scale

    4.2 Reverse phase - linear gradient (preparative scale)

    4.3 Size exclusion

5. Derivatization Methods for Organic Concentrates

    5.1 Silver nitrate ($AgNO_3$)

        5.1.1 Reaction method
        5.1.2 Removal of excess $AgNO_3$

            1.2.1 HCl addition
            1.2.2 Chloride-form anion exchange resin
            1.2.3 H_2S addition

    5.2 4-Nitrothiophenol (NTP)

    5.3 Silver nitrate/HPLC separation

        5.3.1 Reaction method
        5.3.2 AgCl precipitation
        5.3.3 HPLC separation

DESCRIPTION OF METHOD

Apparatus*

1. Prototype concentrator

Pump, Altex 110A, 0.1-9.9 mL/min, 0-5000 psi
Columns (4), Alltech Associates, 1.0 X 50 cm (1/2" 316 SS tubing), 1/2" to 1/16" Swagelok or Parker end fittings, 2 μm frits

Union, 1/2" drilled out (extender for packing columns)
Tubing, 1/16" 316 SS, 1 mm i.d.
Detector, Altex UV (254 nm), biochemical flow cell
Resin packings (50-60 cc per column)
    MP-1 anion exchange resin (Bio-Rad), 45-75 μm

    MP-50 cation exchange resin (Bio-Rad), 45-75 μm
    XAD-2 nonionic resin (Rohm and Haas), 45-75 μm
    XAD-7 nonionic resin (Rohm and Haas), 45-75 μm

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* Does not include items commonly available in analytical laboratory.

2. High-volume concentrator

   Pump, Milton Roy FR-141-144, 10-800 mL/min, 1500 psi
   Pump, Fluid Metering Inc., RP-P-1-CSC, 0-200 mL/min, 100 psi
   Columns (4), 4.9 X 610 cm (2" 316 SS, Schedule 80)
   Columns (4), 4.9 X 610 cm (2" 316 SS, Schedule 80)
      Welded pipe, threaded both ends, 3000 psi caps
      tapped for 1/8" NPT to 1/8" Swagelok connector,
      5-10 μm frits

   Column, 4.9 X 100 cm, as above
   Tubing, 1/8" 304 SS
   Detector, Altex UV (254 nm), biochemical flow cell, splitter
   Resin packings (as for prototype), 1200 cc each,
      1500 cc MP-1

3. Grinding and Sieving

   Ball mill and burundum cylinders, large and small
   Screens, 325 and 200 mesh (45 and 75 μm)
   Peristaltic pump, dual head
   Filter, Carborundum K-27 glass fiber 3 μm

4. Sample Collection

   Filter, Carborundum K-27 glass fiber, 3 μm
   Pump, Fluid Metering Inc., RP-F-2-CSC
   Bottle, Pyrex, 20 L
   Drum, 316 SS, 200 L
   Tubing, Teflon® FEP

5. Solvent Evaporation

   Steam bath
   Kuderna-Danish (K-D) concentrators (10 mL receivers,
      250 and 500 mL flasks, 3-ball Snyder condensers)
   Micro-Snyder concentrators (10 mL receivers as for K-D,
      2-ball micro-Snyder condensers)

6. Fractionation

   Gradient liquid chromatograph, Hewlett-Packard
      1084B with scanning variable wavelength detector
   Column, Whatman Partisil-10 ODS-2, 4.6 X 250 mm
   Column, Whatman Partisil-10 ODS-2, 9.4 X 250 mm
   Column, Dupont Zorbax PSM 60-S, 6.2 X 250 mm
   Teflon® rotary valve, Rheodyne, 6-position, with
      pneumatic actuator

Procedures

1. Column Preparation

   1.1 Columns and fittings. Wash thoroughly in hot soapy water to remove manufacturing residues. Rinse with deionized water, methanol, methylene chloride, and hexane.

   1.2 Grinding resins. Load 5 L ball mill jar with 4.5-5 kg burundum cylinders (typically 100 large and 440 small); add 1 kg XAD-2 or XAD-7 resin and 1.5-2 L methanol. Grind XAD-2 about 4 hours; XAD-7, 30 minutes.

   1.3 Sieving resins.

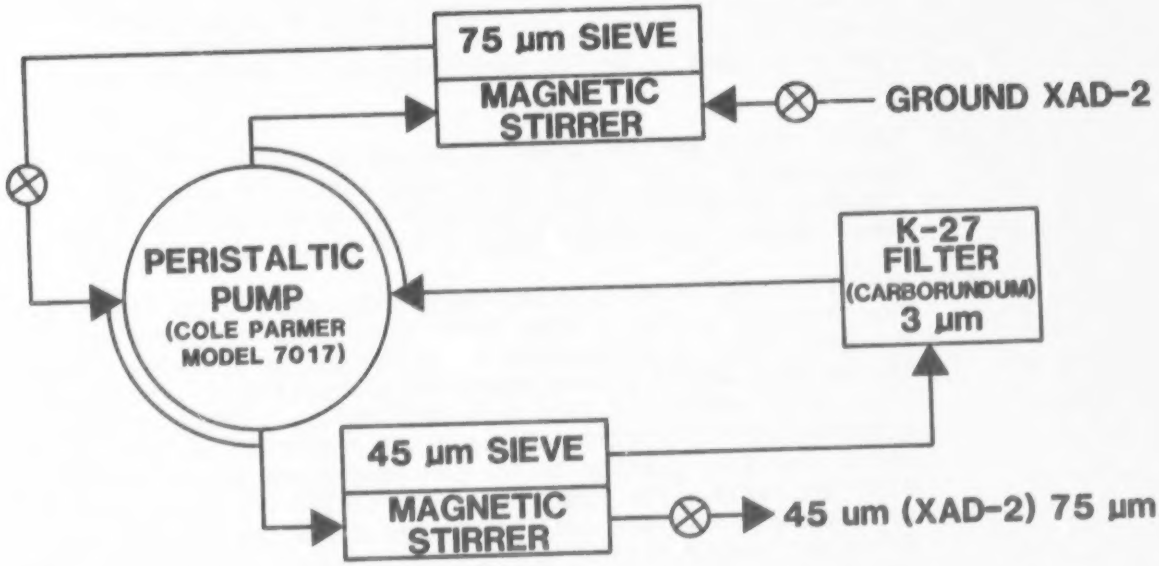
      1.3.1 MP-1 and MP-50. These are 200-400 mesh (75-37 μm) as purchased. Place several grams on an 8-inch, 45 μm screen and wash with a jet of tap water several minutes or until no more particles appear to be going through the screen. Examine product under 80X magnification to verify absence of fines.

      1.3.2 XAD-7. Place several grams of ground slurry on a 75 μm screen which is over a 45 μm screen; wash with water as for MP-1 and MP-50. Save the 45-75 μm particles from the lower screen, and return those >75 μm to the grinding jar.

      1.3.3 XAD-2. Assemble wet-sieving apparatus according to Figure E-1. Use silicone tubing in pump heads for conveying slurry and solvent. Seal joint between sieve and pan by wrapping enough teflon tape around circumference of sieve to give a leakproof fit. Fill both sieve pans with methanol by pouring through screens. With stirrers on, use glass reservoir to feed ground XAD-2 slurry by gravity to the pan underneath the 75 μm screen. With the peristaltic pump, remove particles <75 μm by suction from above the screen and feed to pan below the 45 μm screen. Using the second head of the dual head pump, remove fines (<45 μm) from above the screen, pump through a 3 μm Carborundum K-27 filter, and return filtered methanol to the pan below the 75 μm screen. After stirring for a suitable period, stop slurry flow to the 45 μm screen, switch filtered methanol from the 75 μm pan to the 45 μm pan, and complete processing of batch by stirring and removing fines. Return >75 μm particles to ball mill. Check quality of 45-75 μm product using 80X magnification. Decant methanol after settling and return to system.

   1.4 Slurry packing. Add enough water or methanol to resin in a beaker so that a slurry is formed. Pour the slurry in small portions into a column, open at the top but with the bottom fitting attached, while applying suction at the bottom through a liquid trap. When full, attach the top fitting and pump water, gradually increasing the flow until the expected flow rate is achieved or the pressure

FIGURE E-1
COUNTER-FLOW SIEVING APPARATUS USED FOR RESIN PARTICLE SIZING



maximum of the pump is reached. Maintain the flow for awhile, then stop flow, equilibrate column to atmospheric pressure, remove inlet fitting and add resin, if necessary. (On prototype columns, use of column extender allows column to be fully packed in one step). Assemble columns as shown in Figure E-2.

1.5 Resin purification.

1.5.1 MP-1. Pump 1 *N* HCl, 1 *N* NaOH, and 1 *N* HCl, monitoring absorbance at 254 nm to ensure complete elution of contaminants. Then pump water followed by methanol, acetonitrile, diethylether, and methanol until absorbance at 254 nm appears to be removed (can save solvents for cleanup of other columns). Obtain column blanks with sample eluants, e.g., 4.5 *M* NaCl and acetonitrile, to establish levels of contamination and possible interference.

1.5.2 MP-50. Pump 1 *N* NaOH, 1 *N* HCl, and 1 N NaOH, followed by water and organic solvents (as for MP-1); then obtain column blanks for expected elution solvents for samples (e.g., 4.5 *M* NaCl, acetonitrile).

1.5.3 XAD-2. Pump 1 NaOH, 1 *N* HCl, water and organic solvents (as for MP-1); then obtain column blank for acetonitrile.

1.5.4 XAD-7. Pump methanol, acetonitrile, and water; then obtain column blank for acetonitrile.

2. Sampling

2.1 Preparation of equipment

2.1.1 Filter. Soak Carborundum K-27 glass fiber cartridge overnight in acetonitrile; drain and dry in 100°C oven. Store methanol in cartridge holder, pump, and lines until day of use; empty and flush with deionized water before going to sample site, then flush again with sample at site.

2.1.2 Glass bottles - TOC and VOA. Rinse with deionized water, air dry, and bake in muffle furnace 4 hours at 550°C.

2.1.3 Glass bottles - coliform. Add sodium thiosulfate; autoclave.

2.1.4 Glass bottles - water quality and trace organic analyses. Wash with detergent, rinse; acid wash with H_2SO_4-"No-Chromix" rinse with deionized water.

2.1.5 Stainless steel drum - trace organic analysis. Rinse new drum with methanol, acetonitrile, chloroform, and hexane until blank residue is negligible. Between

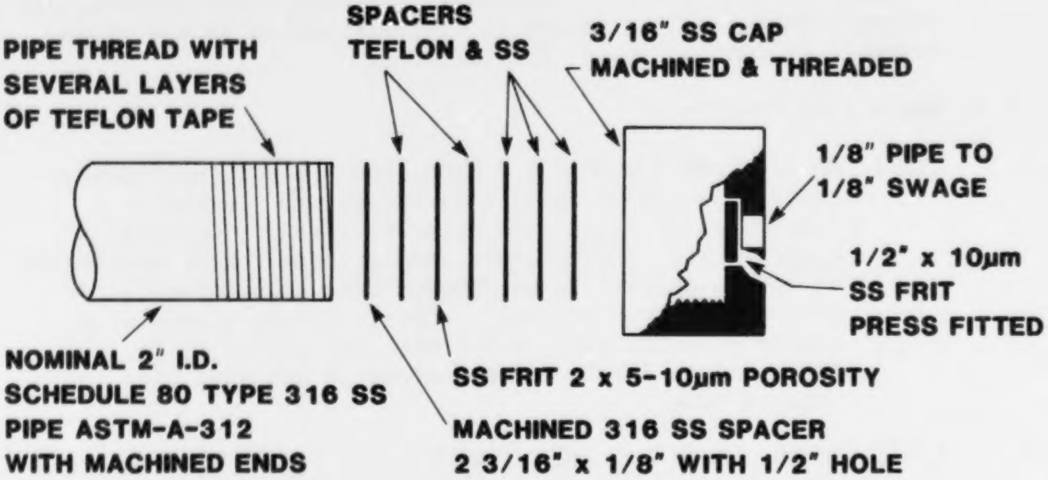


FIGURE E-2 CONCENTRATOR COLUMN END FITTINGS uses, rinse with methanol, then deionized water and allow to dry thoroughly before replacing lid.

2.2 Sample collection. Fill TOC, VOA, coliform and WQA bottles directly from source (unfiltered), TOC and VOA with no headspace in bottle. Rinse pump and filter with about 5 L water, then collect sample for trace organic analysis at rate of about 1 L/min.

3. Trace organic isolation

3.1 Columns. Connect columns in order MP-1, MP-50, XAD-2, and XAD-7 as shown in Figure E-3. Use MP-1 guard column with high-volume system. Use flow splitter to send small part of column effluent to UV detector. If sample size is to be less than 100 L on high-volume system, displace acetonitrile with distilled water, purified by passing through a precolumn containing a mixture of MP-1 and XAD-2.

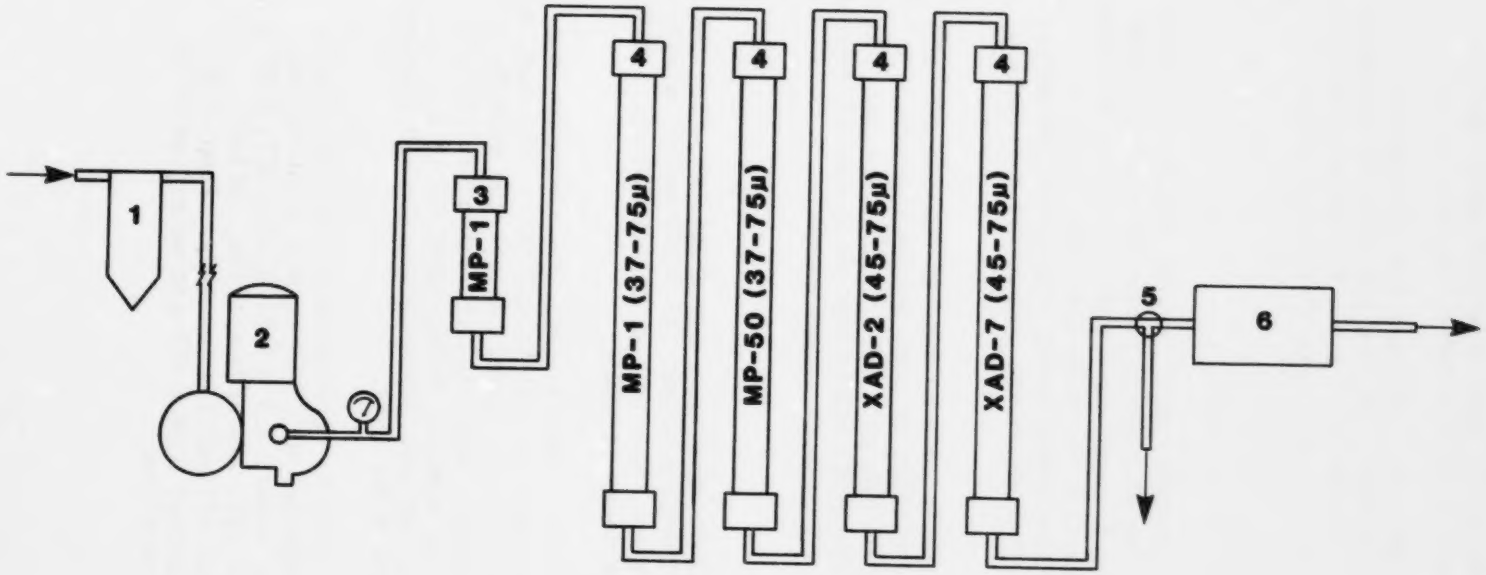
3.2 Adsorption. Pump water sample onto columns at maximum achievable rate, within pressure limitations of pump and back-pressure of columns; typically 10 mL/min for prototype, 150 mL/min for high-volume concentrator. Continue overnight with timer on system if necessary. Record UV absorbance for evidence of breakthrough.

3.3 Elution

3.3.1 Reagents. For aqueous elutions, use distilled water that has been passed through a column (49 X 100 mm) of mixed MP-1 and XAD-2 resins. Use NaCl which has been in a muffle furnace at least 4 hours at 550°C.

3.3.2 Filter. Remove filter from housing, drain briefly, and immerse in acetonitrile in a glass cylinder. The next day, decant the acetonitrile and save. Repeat the soak/decant cycle three more times, combining the extracts. Saturate with NaCl to form an aqueous phase, separate in a separatory funnel, and save acetonitrile for K-D evaporation (designated "Sample #-R-A-CF").

3.3.3 MP-1 column(s). Elute in reverse direction (backflush) at 10 mL/min (prototype) or 25-50 mL/min (high-volume) with acetonitrile, water, 4.5 $\underline{M}$ NaCl/0.04 $\underline{N}$ HCl, 0.04 $\underline{N}$ HCl (until effluent pH <3), and acetonitrile; collect organic and aqueous effluents separately. Pump each elution solvent (except 0.04 $\underline{N}$ HCl and water) until UV trace returns to baseline.



(1) CARBORUNDUM K-27 3.0 μm FILTER IN A 90 x 270mm STAINLESS STEEL HOLDER
(2) MILTON-ROY FR 141-144 TEFLON HIGH-PRESSURE PUMP
(3) GUARD COLUMN, 49 x 100mm, STAINLESS STEEL
(4) MAIN COLUMNS, 49 x 610mm, STAINLESS STEEL
(5) SPLITTER
(6) UV DETECTOR (254nm), 200 μl HPLC BIOCHEMICAL CELL (ALTEX 153)

FIGURE E-3 MACROPOROUS RESIN CONCENTRATION SYSTEM

3.3.4 MP-50 column. Backflush with acetonitrile, water and 4.5 M NaCl; collect aqueous and organic effluents separately.

3.3.5 XAD-2 and XAD-7 columns. Backflush with acetonitrile.

3.4 Extraction

3.4.1 Acetonitrile effluents. Saturate acetonitrile effluent from each column with NaCl; shake in separatory funnel and add the aqueous layers from MP-1 and MP-50 to their respective aqueous effluents. Pool the acetonitrile layers into a composite ("Sample #-R-A-1,50,2,7").

3.4.2 Aqueous effluents. Saturate the aqueous effluents from MP-1 and MP-50 with NaCl; adjust the MP-1 solution to pH 1 (HCl) and the MP-50 to pH 11 (KOH), and extract each three times with acetonitrile ("Sample #-R-A/N-1 and -50").

3.4.3 Influent and effluent water. If the concentrator influent and effluent water are to be extracted to determine removal efficiency, saturate desired volume with NaCl and extract with acetonitrile, first at pH 1 and then at pH 11 ("Sample #-R-A-Inf and -Eff").

3.5 Evaporation

3.5.1 Kuderna-Danish. Evaporate acetonitrile using 500 mL K-D apparatus in steam bath (water is removed with acetonitrile at 76.5°C). Reduce volume to 10 mL (do not allow receiver to go dry); boiling point should be 81°C. Separate each acetonitrile residue from precipitated salt and store in vials with Teflon cap liner in freezer.

3.5.2 Micro-Snyder. When necessary for fractionation or Ames test procedures, make a composite solution from equal proportions of residues and evaporate to slightly less than desired volume in 10 mL receiver with 2-ball micro-Snyder condenser. Add solvent if necessary.

3.5.3 Air-vacuum. To achieve volumes less than 1 mL, transfer residue to small vial; using a disposable Pasteur pipet attached to a vacuum source, draw air from above the liquid, causing evaporation of the solvent. Warm the vial with the fingers and continue until the desired volume is reached.

4. Fractionation

4.1 Reverse phase - step gradient

4.1.1 Analytical scale. Inject 50 µL or less of acetonitrile residue containing the equivalent of 2 mg or less TOC onto a 4.6 X 250 mm ODS-2 column; flow = 1-2 mL/min, 10% CH_3CN/90% H_2O (V/V); step gradient to 30%, 50% and 95% CH_3CN after UV trace drops near baseline for each elution solvent. Make multiple injections if necessary. Collect fractions (1 = 10%, 2= 30%, 3 = 50%+95% CH_3CN) using automatic rotary valve.

4.1.2 Preparative scale. Inject 0.5 mL or less of acetonitrile residue containing the equivalent of 20 mg or less TOC onto a 9.4 X 250 mm ODS-2 column; flow = 4-8 mL/min, 10% CH_3CN/90% H_2O (V/V); step gradient to 30%, 50% and 95% CH_3CN after UV trace drops near baseline for each elution solvent. Make multiple injections if necessary; collect fractions 1, 2 and 3 (as above) using rotary valve.

4.2 Reverse phase - linear gradient (preparative scale). Inject 0.5 mL or less of acetonitrile residue containing the equivalent of 20 mg or less TOC onto a 9.4 X 250 mm ODS-2 column; flow = 4 mL/min, 20% CH_3CN/80% H_2O (V/V). Increase CH_3CN at about 3%/min to 95% CH_3CN, then hold; collect fractions manually from capillary outlet of detector, either at convenient breaks between peaks to give 6-12 fractions or every 0.5 min. = 2 mL to give up to 72 fractions.

4.3 Size exclusion. Inject 40 µL or less of acetonitrile residue containing the equivalent of 1 mg or less TOC onto a 6.0 X 250 mm Zorbax PSM-60S column; flow = 1 mL/min CH_3CN. Collect fractions manually, changing receiver at breaks between peaks.

5. Derivitization Methods for Organic Concentrates

5.1 Silver Nitrate ($AgNO_3$)

5.1.1 Reaction Method. Using previously measured Ames activity, calculate amount of sample concentrate required to give a reasonably high mutagenic response while avoiding toxicity and use of excessive proportion of sample. A mutagenic ratio in the 3-4 range or greater is usually sufficient to allow detection and measurement of a change in activity after derivatization. (For GC/MS, use 2% original sample).

Transfer the desired aliquot (usually 0.1-1.0% of original sample) to a screw-cap vial with Teflon cap liner and add 250 mL of 0.1 M $AgNO_3$ in acetonitrile.

Heat in water bath at 65°C or a hot plate at low setting for 10 minutes. Run duplicates; set up duplicate controls to which 20 μL acetonitrile is added instead of $AgNO_3$.

5.1.2 Removal of excess $AgNO_3$

1.2.1 HCl addition. Add 7 μL of 6N HCl to the cooled reaction mixture from Procedure 1.1; coagulate the AgCl precipitate by heating 10 minutes as before. Withdraw the supernate via syringe and use "as is", or filter through 0.5 μm polytetrafluoroethylene (PTFE). Reduce volume to 200 μL by applying continuous suction from a Pasteur pipet placed about 1 cm above the surface of the sample in a small vial.

1.2.2 Chloride-form anion exchange resin. Weight 75-5 mg quantities of 45-75 μm MP-1 (Bio-Rad) anion exchange resin in Cl^- form into BAS (Bioanalytical systems, Inc.) centrifugal microfilters equipped with 0.5 μm PTFE filters.

Transfer supernate from Procedure 1.1 to the microfilter sample chamber and centrifuge for 10 minutes at 2000-3000 rpm. Rinse resin with acetonitrile and spin again; repeat. Reduce volume of filtrate to 200 μL (See Procedure 1.2.1).

1.2.3 H_2S addition. Working in a fume hood, bubble H_2S gas from a gas-tight syringe into the cooled reaction mixture from Procedure 1.1. Check for completeness of reaction after precipitate settles by adding more H_2S. Filter supernate through 0.5 μm PTFE; remove excess H_2S by bubbling with argon. Reduce volume to 200 μL (See Procedure 1.2.1).

5.2 4-Nitrothiophenol (NTP)

Calculate an amount of sample to give a suitable Ames test response before and after derivatization, as for $AgNO_3$; note that excess NTP may also contribute to mutagenicity. (For GC/MS, use 2% of original sample). Place aliquot into a small screw-cap vial with Teflon cap liner and add 50 μL of freshly made 0.1 M ammonium hydroxide in water and 20 μL of a 4 μg/μL solution of NTP in acetonitrile. React 30 min. at ambient temperature, then dilute to 200 L with acetonitrile.

5.3 Silver Nitrate/HPLC separation*

5.3.1 Reaction method. Add 0.1 M $AgNO_3$ (in CH_3CN) to a sample concentrate in the ratio of 100 μL $AgNO_3$ solution per 0.5% of total sample residue (e.g., the residue equivalent to 1 L of a 200 L sample). Heat ten minutes at 70-80°C in a sealed screw cap vial with PTFE cap liner. Run sample duplicates; run controls with no $AgNO_3$ added.

5.3.2 AgCl precipitation. Add 2 μL 6 N HCl per 100 μL 0.1 M $AgNO_3$; heat for ten minutes as in 5.3.1 to coagulate the AgCl precipitate. Filter through a 0.5 μm PTFE membrane. Reduce volume to <50 μL by applying continuous suction from a Pasteur pipet placed about 1 cm above the surface of the sample in a small vial.

5.3.3 HPLC separation. Inject entire volume from 5.3.2 onto a Whatman ODS-2 HPLC column, 4.6 x 250 mm, with HPLC-grade water flowing at 1.5 mL/min. Discard the initial column effluent, which contains any remaining free $AgNO_3$ and some polar, non-mutagenic sample components. After 5 minutes, change the mobile phase from water to acetonitrile; collect the column effluent from the time CH_3CN first emerges (about 7 minutes from initial injection) until the UV detector signal returns to baseline (12-13 minutes from injection). Reduce the volume to <200 μL by micro-Snyder evaporation and by suction as in 5.3.2.

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*This method is more efficient than Method 5.1.2 in separating excess Ag^+ from the treated sample residue so that silver does not contribute to toxicity in the Ames test.

APPENDIX F

ORGANIC ANALYTICAL METHODS

TOTAL ORGANIC CARBON

Introduction

Total Organic Carbon (TOC) analyses were performed on an Oceanography International Corp., TOC analyzer using the ampule method. Samples are oxidized under heat and pressure in sealed ampules; the resulting CO_2 generated from organic carbon is measured by an infra red (IR) detector.

Procedures

I. Cleaning of Glassware

A. Ampules. Remove any particles of foreign material from glass ampules. Place one inch square light-weight aluminum foil over the top of the ampule neck and twist to form a cover for the ampule. Place ampules in a basket and combust them in a muffler furnace at 550°C for at least 4 hours to remove volatile organics.

B. Drying Tubes. There are three drying tubes in the front panel of the ampule analyzing unit. The first tube on the left is a water vapor trap to remove gross amounts of water vapor. This tube is not filled with magnesium perchlorate and does not need to be cleaned unless it is dirty, (in that case, use acid washing). The second and third tubes are filled with magnesium perchlorate. Empty the magnesium perchlorate whenever wet, rinse tubes with deionized (DI) water, dry them in a 103°C oven and filled them loosely with magnesium perchlorate. Do not pack tightly since it will restrict the gas flow.

C. Glass Purge Tubes and Cones. Clean by drawing boiling distilled water through them with suction or by soaking them in 20% V/V H_2SO_4.

II. "Clean Water" Preparation

A. Glassware. The 5 liter boiling flask, the reflux column and receiving flask are acid washed with "No-Chromix" and rinsed with Barnstead water. The receiving flask is also rinsed with the initial 100 mL aliquot of "clean water" produced by the still.

B. $KMnO_4$ Solution. Use 0.05 moles $KMnO_4$ crystals and 0.05 moles of KOH pellets. This assures that the $KMnO_4$ and KOH concentrations are at least 0.01 M. As water vapor boils off, the concentration of these compounds will increase to approximately 0.03 M. The water source for the $KMnO_4$ still is Barnstead water. The receiving flask is heated at a low setting on the hotplate and purged with N_2 gas.

III. Standards and Reagent Preparation

A. Standards:

1. KHP ($KHC_8H_4O_4$) 1000 mg/L C. Dry KHP at 103°C for one hour, then store in dessicator. Dissolve 2.125 g of KHP into 1000 mL "clean water". Store the water used to prepare the standard in a separate bottle and keep it refrigerated before blank analysis.

2. Na_2CO_3, 1000 mg/L C - Used for inorganic carbon determination. Dry Na_2CO_3 at 103°C for one hour. Store in a dessicator. Dissolve 8.824 g of Na_2CO_3 in 1000 mL "clean water". Adjust the pH of the solution to 7 (using 0.05 N NaOH).

   (Both KHP and Na_2CO_3 standards are good for three months if refrigerated.)

B. Reagent:

1. 10% H_3PO_4 - Use "clean water" to prepare this solution.

   Standards and the 10% H_3PO_4 solution should be kept in glass stoppered bottles and stored in the refrigerator.

IV. Sample Preparation

A. Sample Size. The actual sample size should be experimentally determined for each sample type. It is advisable to keep the carbon range of the sample in the ampule between 5-25 μg. For best results, the total volume of the sample in the ampule should be between 5-8 mL. Whenever the sample aliquot is less than 5 mL, appropriate volume of "clean water" blanks should be prepared. When no dilution water is used, a reagent blank correction will be required. A few examples are given below:

Sample Aliquot	Water Blank	
5 - 8 mL	0 mL	Use reagent blank to correct final results.
4 mL	1 - 4 mL	Use water blanks to correct integrated peak areas of samples
3 mL	2 - 5 mL	
2 mL	3 - 6 mL	
1 mL	4 - 7 mL	

B. Filling the Glass Ampules. All samples, standards, and blanks have to be prepared in triplicate.

1. Samples - In each ampule add:

   0.2 g $K_2S_2O_8$
   sample aliquot
   dilution water
   200 μL of 10% H_3PO_4

   Then purge and seal ampules.

2. Standards - In each ampule add:

   0.2 g $K_2S_2O_8$
   5 mL "clean water"
   5, 10, 15, 20, & 25 μL of 1000 mg/L C (KHP std.)
   200 μL of 10% H_3PO_4

   This will give a 5-25 μg C standard curve.

   Then purge and seal samples. If the sample has a carbon concentration lower than 5 μg or higher than 25 μg, prepare a different standard curve.

3. Blanks - In each ampule add:

   0.2 g $K_2S_2O_8$
   5 mL "clean water"
   200 μL of 10% H_3PO_4

   Then purge and seal ampules.

4. Reagent Blank - In each ampule add:

   0.2 g $K_2S_2O_8$
   1,2,3,4, & 5 mL "clean water"
   200 μL of 10% H_3PO_4

   Then purge and seal ampules. The reagent blank ($K_2S_2O_8$ and H_3PO_4) should be between 0.12 - 0.16 mg/L C (the value of the reagent blank should be determined everytime a new reagent bottle is used). The reagent blank ampules are analyzed and the integrated peak area for each volume of contained water is determined. Integrated peak area is plotted versus the volume (mL) of water. The curve is extrapolated to zero mL. The integrated peak area at the zero mL point is then that portion of CO_2 area resulting from the reagent blank. The mg/L C for the reagent blank is determined from the standard curve.

V. Analysis and Calculations

A. Ampule Method.

1. Since it takes at least 4 hours of warm-up time to thermally equilibrate the IR analyzer, power should be left on at all times as long as the unit is used on a routine basis.
2. Open main valves on nitrogen and span gas (compressed N_2 which contains approximately 408 ppm CO_2) cylinders.
3. Place the standardization vial in the ampule breaking assembly.
4. Position the two-way valve to "out-to-analyze" position so that the IR carrier gas (N_2) flows through the ampule, breaking assembly.
5. Open the "flow" and "zero gas" (N_2) toggle valves.
6. Adjust the IR "rate valve" to give a flow of 200 mL/min (reading of 13).
7. Allow system to purge, then zero the IR analyzer.
8. Close the "zero gas" toggle valve and open the "span gas" toggle valve.
9. Check "span gas" flow rate for 200 mL/min (reading of 13). If necessary, adjust delivery pressure of span gas regulator until the reading of 13 is attained.
10. Allow system to purge with span gas until the IR analyzer meter reaches a maximum.
11. Adjust span control on the IR analyzer to give a reading of 85 at range 1 for a span concentration of 408 ppm. If other span gas concentrations are being used, see calibration curve.
12. Place two-way valve to "IR bypass" or "IN" position.
13. Adjust the "purge rate" valve to give a flow of 200 mL min (reading of 13).
14. Position the two-way valve to "out to analyze" position.
15. Turn flow toggle valve off.

16. Place sample ampule in unit (plastic adaptor and gum rubber seal on ampule).

17. Push the stainless steel purge tube down close to the top of the ampule.

18. Turn flow toggle valve on.

19. Purge system until IR analyzer meter shows zero.

20. Turn flow toggle valve off and wait for flow rate to fall to zero.

21. Raise purge tube above plunger cutter.

22. Break ampule top and push purge tube to within 1/8" of ampule bottom.

23. Turn flow toggle valve on and check if flow is still at the setting of 13.

24. Allow gaseous contents of ampule to pass into the IR analyzer.

25. When the electronic integrator reading reaches a maximum value, turn flow toggle off, remove ampule, clean assembly, and place the next ampule in the breaking ampule assembly.

26. Record the electronic integrator reading and zero the integrator. If reading drifts, re-zero the IR analyzer.

B. Calculations

1. Average the integrated peak area readings for each sample, blank, and standard (X_S, X_{BLK}, X_{STD}).

2. Determine the corrected integrated peak area reading for each standard corrections ($X_{STD} = X_{STD} - X_{BLK}$).

3. Plot a standard curve using the corrected integrated peak areas versus μg of C.

4. If dilution water has been used with the sample, determine the corrected integrated peak area reading for the sample correction ($X_{SAMP} = X_S - X_{BLK}$).

5. Using the standard curve, determine the μg C in the sample.

6. The C concentration in the sample will be:

$$\frac{\mu g\ C\ \text{(determined from standard curve)}}{\text{volume of sample used (mL)}}$$

7. If dilution water has not been used with the sample, skip step 4, and correct the C concentration in the sample with the reagent blank value: µg/mL C in sample - µg/mL C in reagent blank.

Notes:

1. A glass wool filter has been placed at the outlet of the ampule breaking assembly to prevent small particles of glass from clogging the plastic gas lines leading from the assembly to the first water removal tube. Replace the glass wool plug whenever necessary.

2. Whenever a reduction in the carrier gas flow (N_2) is noted, check the stainless steel purge tube. Small glass particles might be causing the reduced flow. In that case, push a steel wire through the tube and clean it. Reduction in the carrier gas flow could also occur whenever the magnesium perchlorate in the drying tube becomes exhausted or whenever the center hole of the silicone rubber seal (which seals the purge tube within the ampule cutting plunger) is enlarged.

3. Samples with high level of chlorides concentration should not be analyzed with the TOC unit. The gases eluting from the ampules, containing chlorine (from the oxidation of chlorides) are extremely corrosive to the analyzer's sample cell.

4. The detection limit for the ampule method is 100 µg/L C.

PROCEDURES FOR THE ANALYSIS OF PURGEABLE TARGET ORGANICS

Introduction

The analytical procedures used for the GC/MS analysis of purgeable target organics (PTO) in this study were developed by laboratory staff members of The Metropolitan Water District of Southern California (F-1), and were based on EPA purge and trap methods for volatile priority pollutants (F-2). The procedures were developed to permit analysis of a volatility range encompassing vinyl chloride to dichlorobenzene isomers with detectability in the sub-microgram per liter range. Basic modifications included an increase in sample size, higher purge temperatures, longer purge times, larger sorbent trap, trap desorption methods, and choice of analytical column.

Procedures

I. Materials

A. Absorbent traps.

1. Pack stainless steel tubing (304 SS; 28 cm x 1/4" o.d.) half full with Chromosorb 102, 60/80 mesh (John-Manville) and half full of Tenax GC, 60/80 mesh (Applied Science). Ends of the tube may be plugged either with silanized glass wool or SS mesh screen (Applied Science).

2. Fit each end of tubes with quick-connect fittings with Viton 'O' rings (Swagelock No. SS-QC4-D-400VT).

3. Condition initially by flushing with helium (40 cc/min) at room temperature, then heat slowly (Ramp) to 220°C. Maintain for each trap 48 hours. Recondition in between samples by backflushing at 220° for 20 min. Traps are blanked just prior to analysis using the procedure described below for sample desorption.

B. Organic-Free Water.

1. Pass double-distilled H_2O through a mixed bed MP-1/XAD-2 resin (45-75 μm) column under pressure.

2. Continuously purge water with He until used.

C. Target Organic Standards.

1. Appropriate standards for target organic mixtures are obtained from Supelco in methanol.

2. Prepare individual standards in methanol from reagent grade chemicals by pipetting appropriate volumes with microsyringe. Concentrations are determined from specific gravity of each.

3. Store stock solutions in methanol at 4°C.

D. Gas Chromatography Column.

1. Pack stainless steel (10ft x 0.125 in o.d.) column with Tenax GC (60/80 mesh).

2. Initially condition under flow in the GC per manufacturer's instructions.

E. Purge Apparatus - Assemble according to Figure F-1.

F. Desorption Apparatus - Assemble according to Figure F-2.

G. GC/MS/DS - Finnigan Model 4023 with INCOS data system.

II. Analysis

A. Purge-and Trap.

1. Assemble apparatus per Figure F-1, with ice bag in place, making sure Tenax half of trap is first in line for adsorption.

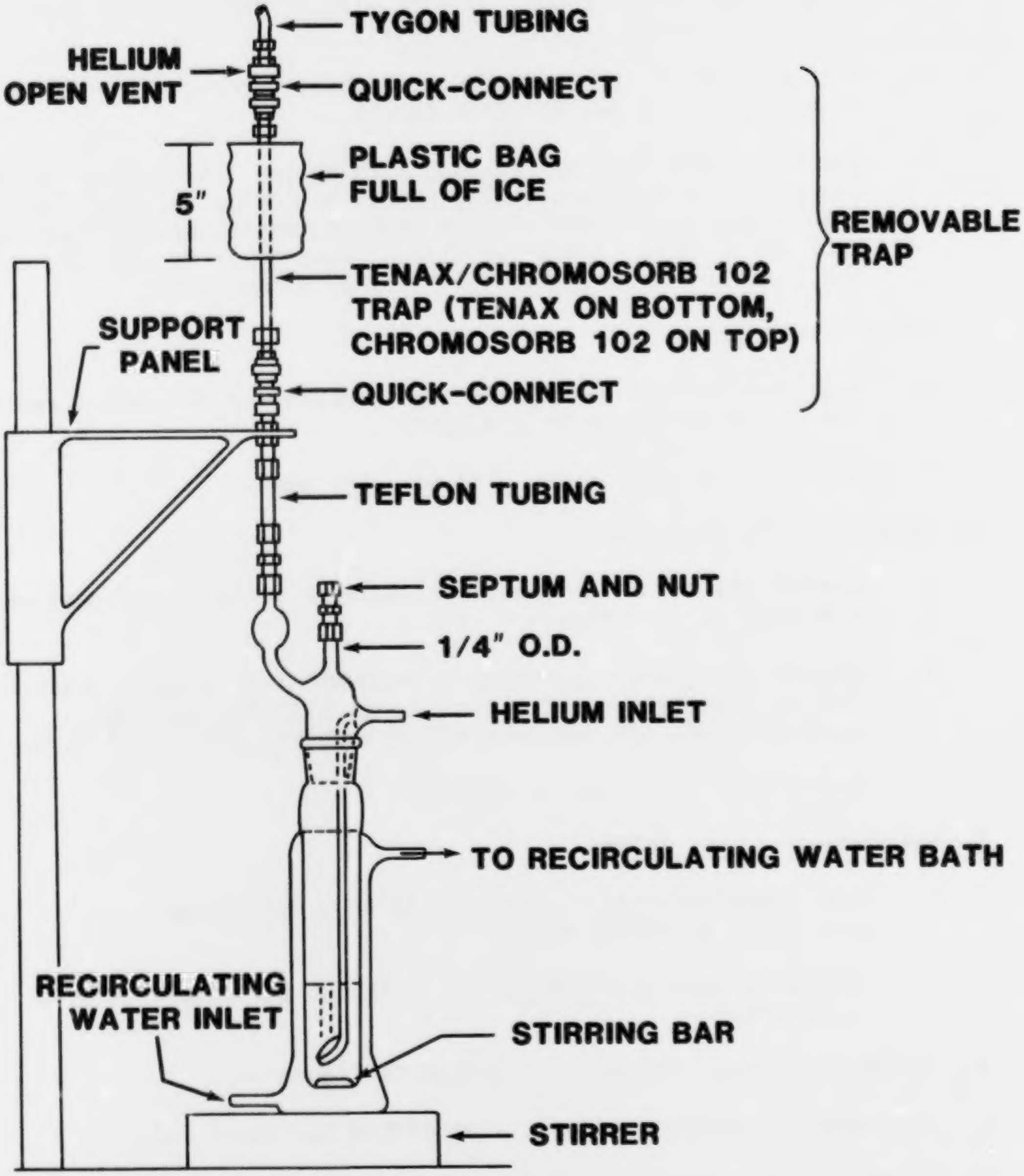

FIGURE F-1 WATER-JACKETED PURGING SYSTEM FOR PTO

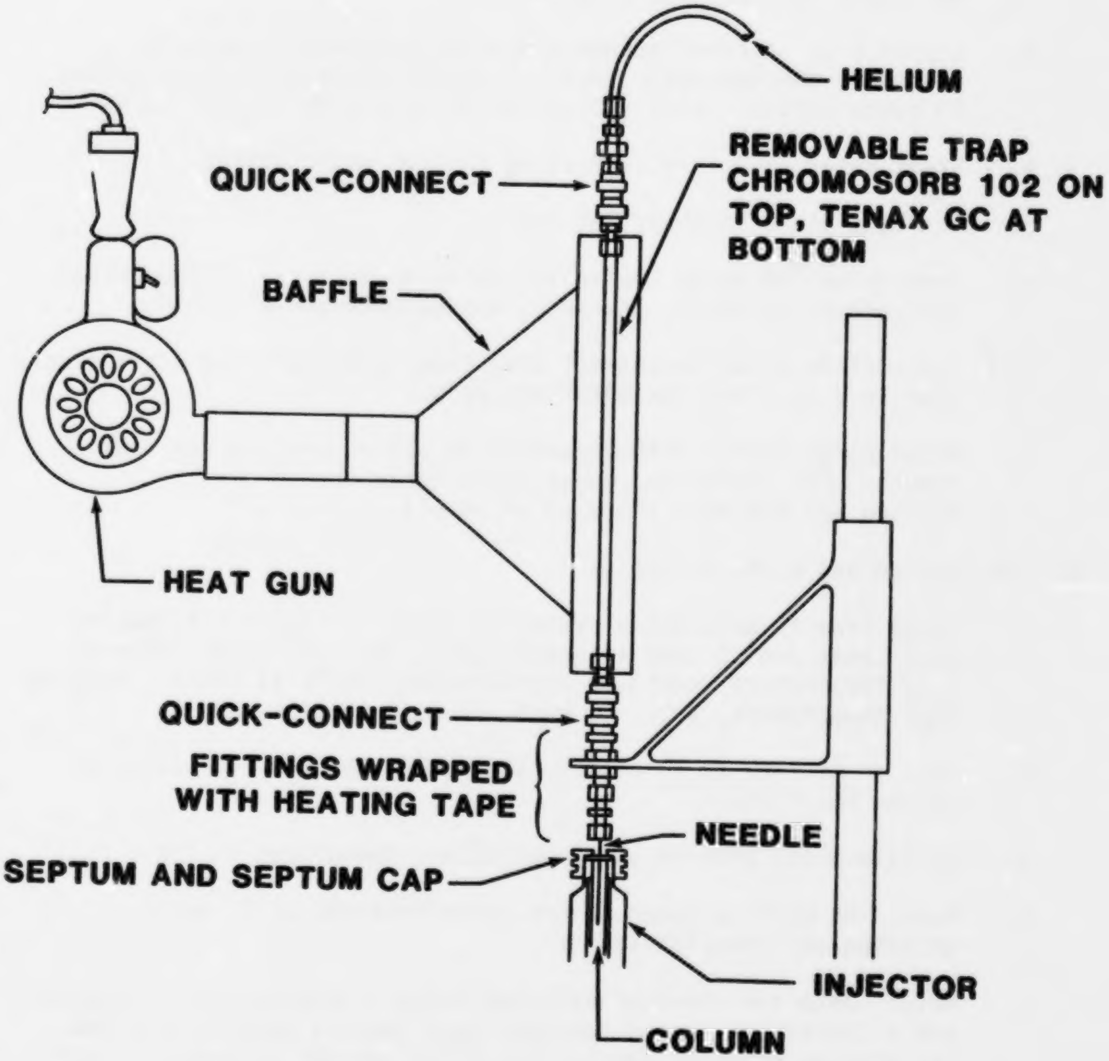
HELIUM
REMOVABLE TRAP CHROMOSORB 102 ON TOP, TENAX GC AT BOTTOM
QUICK-CONNECT
BAFFLE
HEAT GUN
QUICK-CONNECT
FITTINGS WRAPPED WITH HEATING TAPE
NEEDLE
SEPTUM AND SEPTUM CAP
INJECTOR
COLUMN

FIGURE F-2 DESORPTION SYSTEM FOR PTO

2. Transfer 50 mL sample aliquot from crimp-seal sample vial with gas tight syringe into purge bottle.

3. Inject 5 μL internal standard mixture (bromochloromethane, 2-bromo-1-chloropropane, and 1,4-dichlorobutane) through septum in purge bottle; final concentration should be 10 μg/L each.

4. Start water (50°C) recirculating through water jacket.

5. Set stir plate to about 30% MAX.

6. Turn on helium purge (molecular seive on He line) to 85 cc/min (micrometering valve, pre-set), and purge exactly 30 min.

7. Turn off He flow, disconnect trap from apparatus, and store sample trap in a SS pipet box until analysis.

8. Rinse purge bottle with organic-free water; prepare for next sample. For standards, purge rinse water for 15 min., discard and add next standard or sample.

B. Desorption and GC/MS Analysis.

1. Place trap in desorption system as shown in Figure F-2, making sure Tenax end of trap is connected to the oven quick connect. Trap temperature should be approximately 240°C at center; heating tape temperature, 90°C; GC oven, 25-30°C (door open).

2. Turn on He flow at 40 cc/min, and backflush trap onto cold GC column for 4 min.

3. Initiate GC/MS program using conditions summarized in Table F.1.

4. Note: MS must be tuned to EPA specifications (F-3) using decafluorotriphenylphosphine.

5. Note: Data are computer-analyzed using a reverse-search program and a library of target-compound mass spectra developed at MWD. The program examines sample data files for the presence of each target compound within one-minute specified retention time "window", and sample and library spectra are compared for similarity or "Fit". The program quantifies a compound in the appropriate window if it has a Fit exceeding 750 in a similarity index of 1000 (0 = no Fit; 1000 = perfect Fit); quantitation is based on ion intensity of a selected mass for each compound relative to the specified ion for the internal standard. If the analyst observes a PTO Fit of < 900, identification should be verified manually.

TABLE F-1

GC/MS PARAMETERS

Oven Temperature Program

Time (min)	Program Rate	Final Temp. (°C)
0-2	Rapid	110
2-32	5°C/min	260
32-75	Hold	260
Carrier Gas/Flow	He @ 15 mL/min	
Injector Temp	200°C	
Mass Range Scanned	35-260 amu	
Scan Time	2.0 sec	

Detection Limits, Recovery, and Precision

Detection limits and quantitation program data for the PTO are shown in Table F.2. As can be seen, these relative detection limits were in the range of 0.1 - 0.3 μg/L for the individual compounds.

Although reliability data were collected by MWD during method development (F-1), an attempt was made to monitor the quality of routine data during the course of the Health Effects Study. Recovery of components by the analytical methods were assessed in routine analysis by spiking samples with standard mixtures and analyzing them with routine sample sets. Recovery data are summarized in Table F.3. Due to data system and purge system problems, vinyl chloride data are considered unreliable. Most other recovery data are on the high side, and may reflect a slight difference in the commercial standard mixtures used to spike samples (at LACSD) and those used to calibrate the GC/MS (at MWD).

Precision of the overall analytical procedure was evaluated by analyzing a duplicate aliquot of one sample in (usually) each set of samples analyzed. These results (Table F.4) indicate that the precision was good for those components routinely detected. However, since many compounds were not detectable, rigorous statistical treatment of this data was not appropriate.

PROCEDURE FOR THE ANALYSIS OF NON-PURGEABLE TARGET ORGANICS

Introduction

The analytical procedures for the non-purgeable target organics (NPTO) were developed in the San Jose Creek Water Quality Laboratory of LACSD. The compounds which were monitored ranged from 1,2,4-trichlorobenzene to benzo(G.H.I)-perylene in retention times and included 37 compounds. The list of compounds includes two deuterated internal standards, 25 of the 87 EPA non-purgeable priority organic pollutants (F-2), five other isomers of compounds on the EPA list and, five compounds identified in Health Effects Study samples. The entire list of compounds surveyed is presented in Table F.5.

Procedures

I. Materials

A. Gas Chromatography Columns.

1. Glass Wall Coated Open Tubular SE-52 capillary column (25 m x 0.25 mm ID). Supelco, Co.

2. Glass Wall Coated Open Tubular CP-Sil 8 capillary column (26 m x 0.25 mm ID), Chrompack.

3. Fused Silica Wall Coated Open Tubular SE-54 capillary column (30 m x 0.25 mm I.D.), J. & W. Scientific, Inc.

B. GC/MS/DS - Finnigan Model 4023 equipped with a Pulsed Positive Ion Negative Ion Chemical Ionization source was used to acquire data which

TABLE F-2

DETECTION LIMITS AND GC/MS QUANTITATION PARAMETERS FOR PTQ[a], [b]

Compound	Detection Limit (µg/L)	Relative Retention Time	Quantitation Mass (m/z)
Vinyl Chloride	1.0	0.149	62
Methylene Chloride	0.2	0.403	84
1,1-Dichloroethane	0.1	0.529	63
Bromochloromethane(IS1)	[c]	0.597	128
Chloroform	0.2	0.597	83
1,2-Dichloroethane	0.2	0.694	98
Carbon Tetrachloride	0.1	0.719	117
Benzene	0.2	0.754	78
Trichloroethane	0.1	0.760	130
Bromodichloromethane	0.2	0.824	127
1,1,2-Trichloroethane	0.2	0.971	97
Toluene	0.2	0.971	97
Tetrachloroethene	0.3	0.986	164
2-Bromo-1-chloropropane(IS2)	[c]	1.000	77
Dibromochloromethane	0.1	1.056	127
Chlorobenzene	0.1	1.143	112
1,4-Dichlorobutane(IS3)	[c]	1.252	55
Bromoform	0.1	1.283	173
1,4-Dichlorobenzene	0.3	1.450	146
1,2-Dichlorobenzene	0.2	1.500	146

[a] 50 mL sample volume.

[b] Retention times relative to 2-bromo-1-chloropropane (IS2) with an absolute retention time of 16.1 min. on a 10 ft. Tenax GC column.

[c] Not determined.

TABLE F-3

PURGEABLE TARGET ORGANIC COMPOUND RECOVERIES FROM SPIKED SAMPLES

Compound	Percent Compound Recovery From Samples Spiked with 5 µg/L of Each Compound						
Vinyl Chloride	a/	a/	a/	a/	b/	20	26
Methylene Chloride	a/	110	a/	a/	60	114	94
1,1-Dichloroethane	84	110	94	28	66	112	118
Chloroform	93	110	92	120	74	122	108
1,2-Dichloroethane	140	112	90	90	96	132	105
Benzene	104	110	90	76	72	104	108
Trichloroethene	84	94	94	70	82	148	94
Bromodichloromethane	98	84	90	108	116	122	92
1,1,2-Trichloroethane	106	110	110	106	98	132	108
Toluene	95	114	102	104	114	132	100
Dibromochloromethane	96	114	106	100	104	144	102
Tetrachloroethene	97	112	118	98	104	b/	112
Chlorobenzene	126	118	106	96	114	126	110
Bromoform	104	120	90	94	128	128	90
1,4-Dichlorobenzene	64	94	144	76	92	96	106
1,2-Dichlorobenzene	94	94	124	80	112	100	108
Carbon Tetrachloride	150	112	98	86	74	b/	116

a/ Sample data lost due to system malfunction.
b/ Results questionable.

TABLE F-4

RESULTS OF DUPLICATE PURGE-AND-TRAP ANALYSES FOR TARGET ORGANICS

Compounds	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Vinyl Chloride	<1.0	<2.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Methylene Chloride	0.5	0.5	17	18	4.8	5.5	1.0	0.9	7.6	7.1	0.5	0.7	45	45
1,1-Dichloroethane	<0.1	<0.1	2.9	2.8	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chloroform	1.2	1.1	4.7	4.7	0.8	0.8	0.6	0.5	0.8	0.7	0.7	0.8	38	35
1,2-Dichloroethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.3	0.4	<0.2	<0.2
Benzene	0.4	0.4	0.5	0.6	<0.2	0.3	<0.2	0.4	<0.2	<0.2	<0.4	<0.4	0.4	0.2
Trichloroethene	<0.2	<0.2	0.6	0.6	<0.2	<0.2	<0.2	<0.2	0.2	0.2	0.1	0.1	0.5	0.5
Bromodichloromethane	<0.1	<0.1	<0.1	<0.1	1.4	1.5	<0.1	0.1	<0.2	<0.2	0.2	0.1	0.1	0.1
1,1,2-Trichloroethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.1	0.1	<0.1	<0.1	0.2	0.2
Toluene	0.4	0.4	24	25	0.4	0.4	0.2	0.2	<0.2	<0.2	<0.3	<0.3	0.1	0.1
Dibromochloromethane	<0.1	<0.1	0.1	0.1	3.0	3.0	0.2	0.2	0.5	0.4	0.2	0.2	0.1	0.1
Tetrachloroethene	0.4	0.4	4.3	4.4	<0.1	<0.1	0.3	0.3	0.3	0.3	0.2	0.2	a/	a/
Bromoform	<0.1	<0.1	<0.1	<0.1	2.8	3.2	0.1	0.1	0.3	0.3	0.1	0.1	0.1	0.1
Chlorobenzene	<0.1	<0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
1,4-Dichlorobenzene	<0.2	<0.2	8.3	10.6	<0.3	<0.3	2.4	2.8	2.5	2.3	2.3	2.8	2.1	2.0
1,2-Dichlorobenzene	<0.1	<0.1	1.4	1.8	<0.1	0.1	1.3	1.4	0.5	0.4	0.7	0.9	0.6	0.6
Carbon Tetrachloride	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.2	<0.1	<0.1

a/ Not analyzed.

TABLE F-5

GC/MS PARAMETERS FOR NON-PURGEABLE TARGET ORGANICS

Name	Relative Retention Time[a/]	Quantitative Mass	Detection Limits µg/L
1,2,4-trichlorobenzene	0.990	182	0.1
Naphthalene-D8 (IS)	1.000	136	0.2
Phenylacetic Acid	1.219	91	0.7
2,3,5-trichlorophenol	1.405	196	0.2
2,4,6-trichlorophenol	1.459	196	0.2
2,4,5-trichlorophenol	1.472	196	0.2
2,3,4-trichlorophenol	1.498	196	0.4
2,3,6-trichlorophenol	1.541	196	0.2
3,4,5-trichlorophenol	2.171	196	0.9
Hexachlorobenzene	2.368	284	0.1
Simazine	2.460	201	1.1
Pentachlorophenol	2.470	266	1.3
Atrazine	2.487	200	0.5
1,2,3,4,5,6-hexachloro-cyclohexane	2.488	181	0.1
Propazine	2.508	214	0.2
Phenanthrene	2.523	178	0.2
Anthracene-D10 (IS)	2.534	188	0.2
2,2',5-trichloro-1,1'-biphenyl	2.540	186	0.1
2,3',5-trichloro-1,1'-biphenyl	2.702	256	0.1
2,2',4,4'-tetrachloro-1,1'-biphenyl	2.924	220	0.2
Aldrin	2.939	263	0.2
Fluoranthene	3.122	202	0.2
2,3',4',5-tetrachloro-1,1'-biphenyl	3.143	292	0.2
O,P'-DDE	3.247	246	0.9
2,2',4,5,5'-pentachloro-1, 1'-biphenyl	3.257	326	0.3
Dieldrin	3.363	79	0.9
P,P'-DDE	3.380	246	0.2
2,2',3,3',6,6'-hexachloro-1, 1'-biphenyl	3.388	360	0.3
Endrin	3.488	263	1.2
O,P'-DDT	3.552	235	0.5
2,2',4,4',5,5',-hexachloro-1, 1'-biphenyl	3.594	360	0.4
P,P-DDT	3.689	235	0.9
Butylbenzylphthalate	3.699	149	b/
Di-(2-ethylhexyl)phthalate	4.039	149	0.5
Benzo(a)pyrene	4.509	252	0.7
Indeno(1,2,3-c.d.)pyrene	7.340	276	0.7
1,12-benzoperylene	5.139	276	1.0

a/ Relative to Napthalene D8 with a retention time of 12.01 minutes.
b/ Not determined.

were stored and processed with an INCOS data system equipped with two top loading Perkin Elmer disc drives for high speed data retrieval, and a magnetic tape drive for bulk data storage.

C. Non-Purgeable Target Standards.

1. Anthracene-D10 standard solutions were prepared from Lot #090787LC of Aldrich Analyzed Anthracene-D10 and J.T. Baker (HPLC grade) acetonitrile at a concentration of 4 μg/μL. This standard was placed at the head end of the concentration column before samples were concentrated as a system-wide internal standard.

2. Naphthalene-D8 standard solutions were prepared from Lot #85177DAE of Aldrich Analyzed Naphthalene-D8 and J.T. Baker (HPLC grade) acetonitrile at a concentration of 1 μg/mL. This solution was used as an internal standard for the calibration of the GC/MS work.

3. A mixed standard of 41 compounds (Table F.5) was prepared from the appropriate standards using acetonitrile with some dichloromethane added as a solvent to give complete solubility of all compounds. The final concentration for each of the components was approximately 50 μg/μL.

II. Analysis

A. Sample Preparation.

1. A two percent composite for each sample was made from the previously concentrated sample residues.

2. Each sample composite was then taken down to less than 180 μL with use of the house vacuum system to remove solvent vapor. Ten μL of the naphthalene-D8 standard were then added, which would give a final concentration of 50 ng/μL, then acetonitrile was added to bring the volume up to 200 μL.

B. GC/MS Analysis.

1. The tune of the MS was checked daily using 1 μL of decafluorotriphenylphosphine (DFTPP) at 100 μg/μL to meet the EPA specifications (F-2). The GC/MS conditions are listed in Table F.6.

2. At the beginning of each day a calibration standard of the 41 compounds was run, after which the NPTO samples were run. The standard and all of the samples were introduced into the GC/MS system as 1 μL injections using a 10 μL Hamilton 701-N Microliter Syringe. Different syringes were used for the standard and the samples. The GC/MS conditions used are listed in Table F.7.

3. Data were computer-analyzed using a reverse-search program and a library of target-compound mass spectra developed in LACSD laboratory. The search routine is like that used for the PTO.

TABLE F-6

GC/MS PARAMETERS FOR DECAFLUOROTRIPHENYLPHOSPHINE (DFTPP) CALIBRATION

Gas Chromatograph

Carrier Gas	He @ 16 psi (constant pressure) (flow 20 cc/min @ 280°C)
Injection Temperature:	220°C

Temperature Program:

Initial Temperature	170°C
Final Temperature	210°C
Program Rate	40°C/min

Injection Mode: Splitless for one minute then split and septum purge valves opened.

Mass Spectrometer

Separator oven:	285°C
Interface:	280°C
Ionizer:	270°C
Manifold:	98°C
Mass Range:	35 - 500 amu
Scan Rate - Up:	0.95 sec
Settling Time-Bottom:	0.05 sec
Electron Energy:	70 eV
Emission Current:	0.30 ma

TABLE F-7

GC/MS PARAMETERS FOR SAMPLES

Gas Chromatograph

Carrier Gas: He @ 16 psi (constant pressure)
(flow 20 cc/min @ 280°C)

Injector Temperature: 220°C

Temperature Program:

Time (min.)	Rate	Temp (°C)
0-2	Constant	40
2	Rapid	60
2-57	4°C/min	280
57-65	Hold	280

Injection Mode: Splitless for one min. then split and system purge valves opened

Mass Spectrometer

Seperator Oven:	285°C
Interface:	280°C
Ionizer:	270°C
Manifold:	98°C
Mass Range:	35 to 500 amu
Scan Rate:	Up 0.95 sec Settling Time-Bottom 0.05 sec
Electron Energy:	70 eV
Emission Current:	0.30 ma

III. Standard Recovery

Accuracy of the NPTO concentration/analytical process was estimated by a series of compound recovery experiments with reclaimed water and tap water. In order to avoid mass balance problems from loss of standards in sample vessels due to adsorption, poor stability, and vaporization, standard mixtures in acetonitrile were spiked directly onto the head end of the resin concentrator. Spike concentrations were equivalent to 10 μg/L. Following this, 100 L of sample were concentrated by methods described in Appendix E, and the resulting concentrates handled as samples described above. Results of these experiments are shown in Table F.8 for both reclaimed water and tap water samples. Recoveries were generally comparable to literature reports for resin concentrators with the exception of poor recovery of chlorinated phenols from some samples and generally poor recoveries for lindane and the heavier PAHs.

PROCEDURE FOR THE HIGH PRESSURE LIQUID CHROMATOGRAPH MASS/SPECTRAL (HPLC/MS) CHARACTERIZATION OF SAMPLES

Introduction

The Finnigan moving belt LC/MS interface was experimented with for the characterization of compounds from sample fractions. The complexity of the sample was so great and sensitivity relative to GC/MS so poor, that no useful information was derived from this work. Very broad peaks were observed in the EI/reconstructed ion chromatograms with very complex spectra. Fraction 30 from a linear gradient program fractionation (Appendix E) of a mutagenic reclaimed water residue (Sample No. 59) was experimented with in detail, but even this subfraction exhibited a molecular complexity which prevented meaningful interpretation of mass spectra.

Procedures

I. Materials and Equipment.

A. LC/MS/DS - Finnigan Model 4023 equipped with a Pulse Positive Ion Negative Ion Chemical Ionization source and LC/MS Interface was used to acquire data which was stored and processed with an INCOS data system equipped with two top loading Perkin Elmer disc drive for high speed data retrieval, and a magnetic type drive for bulk data storage. The LC interface was used with both stainless steel and Kaptan moving belts.

B. HPLC - A Hewlett Packard Model 1084B Liquid Chromatograph with a variable wavelength detector was used to monitor the LC effluent.

C. HPLC Columns.

1. ODS Column: Whatman Partisil PSX10/25 ODS-2 #1H 5847, 4.6 mm x 250 mm; Whatman Partisil PSX 10/25ODS #1F3625 4.6 mm x 250 mm.
2. CN Column Altex Scientific Spherisorb CN 5 μm #255-21, 4.6 mm x 250 mm.

TABLE F-8. PERCENT RECOVERY OF 27 STANDARD MIXTURES[a/]

Compound	RC1	RC2	RC3	TW1	TW2	TW3	TW4	TW5
Anthracene-d10	66.7	66.4	63.8	99.3	77.4	b/	105.0	79.3
1,2,4-trichlorobenzene	23.3	58.1	29.8	83.4	14.2	85	72.5	75.1
2,3,5-trichlorophenol	55.9	65.2	68.2	6.6	11.9	<1	20.1	34.6
2,4,6-trichlorophenol	60.2	66.6	67.4	5.8	12.2	<1	43.9	63.6
2,4,5-trichlorophenol	60.0	55.7	55.2	6.4	13.2	<1	91.2	51.6
2,3,4-trichlorophenol	55.3	55.4	45.2	6.9	13.2	<1	73.4	47.7
2,3,6-trichlorophenol	53.9	45.0	68.4	4.3	11.2	<1	<1	7.7
Pentachlorobenzene	37.0	84.6	52.2	85.2	48.2	83	85.1	62.9
3,4,5-trichlorophenol	48.6	60.9	62.9	9.6	15.7	<1	b/	b/
Hexachlorobenzene	56.0	87.0	63.7	89.8	60.4	93	95.3	71.1
Pentachlorophenol	97.0	75.3	88.2	36.7	30.7	14	185	125
Lindane	16.9	25.7	17.8	13.1	19.9	42	48.6	38.4
2,3,5-trichlorobiphenyl	54.9	81.8	64.1	1.2	10.6	100	104	78.7
2,2',4,4'-tetrachlorobiphenyl	58.3	83.7	62.8	95.3	73.3	107	105	73.4
Aldrin	50.5	88.4	59.7	57.5	58.5	8	99.1	69.0
Fluoranthene	49.4	75.3	57.6	93.5	76.1	1	114	66.4
O,P'-DDE	54.3	86.1	61.4	98.7	79.2	104	103	66.2
2,2',4,5,5'-pentachlorobiphenyl	54.9	86.2	61.5	93.4	72.6	97	101	66.3
Dieldrin	44.8	84.0	50.2	104	53.3	97	96.4	66.0
P,P'-DDE	3.7	105	60.8	113	87.3	107	113	67.3
2,2',3,3',6,6'-hexachlorobiphenyl	53.4	85.4	58.0	98.6	72.7	104	104	69.4
Endrin	50.0	51.1	18.6	27.3	34	3	50.0	16.8
O,P'-DDT	44.6	85.2	33.8	110	76.6	111	108	69.7
P,P'-DDT	42.4	65.8	23.5	107	72.1	115	94.7	70.1
Benzo(a)pyrene	10.0	37.8	12.0	5.9	5.9	<1	58.2	<1
O-phenylenepyrene	13.2	55.1	43.0	<1	58.3	<1	85.7	26
Benzo(g.h.i.)perylene	10.6	50.6	44.2	<1	3.4	<1	79	10

a/ = Standards spiked equivalent to 10 μg/l for each compound. All sample volumes were 100 L of either: RC = reclaimed, or TW = tap water.

b/ = Not in spike mixture used.

II. Analysis

A. Sample Preparation.

1. Sample residue fractions were prepared as described in Appendix E; concentrates represented 1% of total residue in 200 µL CH_3CN.

2. Several standards prepared in CH_3CN were used for calibration purposes.

B. Analysis.

1. Inject 10 µL sample in Rheodyne injector.

2. Start isocratic LC run per conditions in Table F.9.

PROCEDURE FOR THE CHEMICAL IONIZATION MASS SPECTRAL CHARACTERIZATION OF SAMPLES

Introduction

The Positive Ion (PCI) and Negative Ion (NCI) spectra of both samples and fractions were gathered in the Chemical Ionization (CI) mode using methane as a reagent gas. There were generally about the same number of peaks in the PCI and NCI spectra.

The halogen ions (Cl - 35,37, Br - 79, 81 and I - 127) were observable in NCI and those sample components containing these ions were further studied. The effect on the halogen containing peaks, when the samples were treated with silver nitrate or 4-nitrothiophenol (NTP), was monitored in the NCI mode.

Procedure

I. Equipment

A. GC/MS/DS - Finnigan Model 4023 equipped with a Pulse Positive Ion Negative Ion Chemical Ionization source was used to acquire data which were stored and processed with an INCOS data system equipped with two top loading Perkin Elmer disc drives for high speed data retrieval, and a magnetic tape drive for bulk data storage.

B. Gas Chromatograph, Column - Fused Silica, Wall Coated Open Tubular SE-54 capillary column (30 m x 0.25 mm I.D.), J. & W. Scientific, Inc.

C. Reagent Gas - Methane, Ultra Pure.

II. Analysis

A. Sample Preparation.

1. Samples were fractionated using reverse phase HPLC.
2. Each sample fraction was evaporated to 20 µL in a vial.

TABLE F-9

HPLC/MS PARAMETERS

HPLC

ODS2 Column - Flow = 0.4 mL/min; Isocratic conditions - 60% CH_3CN, 40% H_2O.

CN Column - Flow = 1 mL/min; solvent

Solvent A-95% Hexane, 5% methyl-t-butylether.

Solvent B - 70% methyl-t-butylether,

30 % Acetonitrile; Isocratic conditions,

various % B levels.

Solvent flow - 100% of HPLC flow onto belt

Belt - Kaptan, SS

Vaporizer Heater - 240°C

Clean Up Heater - 280°C

Interface Heater - 100°C

Mass Spectrometer

Ionizer - 270°C

Manifold - 98°C

Mass Range - 55-500 amu

Electron energy - 70 eV

Emission current - 0.30 ma

B. GC/MS Analysis.

1. DFTPP was injected daily in the NCI mode to check the system sensitivity and calibration.

2. One μL injections were made of all samples using a 10 μL Hamilton 701-N Microliter Syringe. The GC/MS conditions are listed in Table F.10.

PROCEDURE FOR THE SOLID PROBE MASS SPECTRAL CHARACTERIZATION OF SAMPLES

Introduction

A few attempts were made to characterize sample fractions using the Solid Probe in the temperature programming mode. When the samples were temperature programmed, a constant high bleed of sample components was observed as a high background which had a few very broad peaks exhibiting very complex spectra.

Procedures

I. Equipment

A. MS - Finnigan Model 4023 equipped with a PPINICI ionization source and an INCOS data system was used.

II. Analysis

A. Sample Preparation.

1. Sample Residues were concentrated according to Appendix E.

2. Two percent residue portions were concentrated to ca 20 μL in CH_3CN.

B. MS Analysis.

1. Place 1 μL of sample in glass sample holder.

2. Place holder in probe tip and evaporate solvent.

3. Insert probe back in MS source and start program/ analysis using conditions in Table F.11.

C. Data reduction - search of NBS library with INCOS data system.

TABLE F-10

GC/MS PARAMETERS FOR CHEMICAL IONIZATION

Gas Chromatography

Carrier Gas: He @ 16 psi (constant pressure)
(flow 20 cc/min at 280°C)

Ionization Gas: CH_4 (maintain 0.45 Torr Ionizer pressure)

Injector Temperature: 220°C

Temperature Program:

Time (min.)	Rate	Temp (°C)
0-2	Constant	40
2	Rapid	60
2-57	4° C/min	280
57-65	Hold	280

Injection Mode: Splitless for one min. then split and system purge valve opened.

Mass Spectrometer

Separator Oven: 285°C

Interface: 280°C

TABLE F-11

SP/MS PARAMETERS

Solid Probe

Temperature Program

	Temperature		Rate
	Initial (°C)	Final (°C)	°C/min
1)	-20	300	10
2)	85	300	10

Mass Spectrometer

Ionizer:	150°C
Manifold:	80°C
Ionizer Pressure:	0.45 Torr.
Mass Range:	33-550 amu
Scan Rate:	Up 0.95 sec Settling Time-Bottom 0.05 sec
Electron energy:	95 eV
Emmission Current:	0.30 ma

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TABLE G-1 - RESULTS FROM PURGEABLE TARGET ORGANIC SAMPLING a/, d/, e/

Source	Montebello Forebay Wells																	
	1580J			1566A			2907			1591H			2958A			2947Q		
Target Compound µg/l	UnCl$_2$ Well	UnCl$_2$ Well	UnCl$_2$ Well	UnCl$_2$ Well	UnCl$_2$ Well	UnCl$_2$ Well	Cl$_2$ Well	Cl$_2$ Well	Cl$_2$ Well	UnCl$_2$ Well	UnCl$_2$ Well	UnCl$_2$ Well	Cl$_2$ Well	Cl$_2$ Well	Cl$_2$ Well	UnCl$_2$ Well	UnCl$_2$ Well	UnCl$_2$ Well
Vinyl chloride	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Methylene chloride	2.2	0.4	<0.2	8.9	0.3	0.5	0.4	0.3	<0.2	0.4	1.8	<0.2	0.4	1.8	<0.2	0.9	<0.2	<0.2
1,1-dichloroethane	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	0.3	0.1	<0.1	<0.1	<0.1	0.2	<0.1	0.4	<0.1	<0.1	<0.1
Chloroform	2.6	<0.4	0.2	1.6	1.2	1.2	1.6	<0.4	<0.2	0.4	0.5	<0.2	<0.4	<0.4	<0.2	<0.4	<0.2	<0.2
1,2-dichloroethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Carbon tetrachloride	* b/	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Bromodichloromethane	0.2	<0.1	<0.1	<0.2	<0.2	<0.1	9.1	0.6	1.8	<0.1	<0.1	<0.1	<0.2	<0.2	0.2	0.2	<0.1	<0.1
Trichloroethylene	2.3	<0.2	<0.1	0.2	<0.2	<0.2	<0.2	<0.1	<0.2	0.4	0.6	<0.2	<0.2	<0.2	<0.2	0.3	<0.2	<0.3
Dibromochloromethane	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	43.0	3.2	13	0.2	<0.1	0.1	1.2	1.1	1.8	0.2	<0.1	0.1
1,1,2-trichloroethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Benzene	0.9	<0.2	<0.3	0.2	<0.2	0.4	<0.2	0.3	<0.3	<0.2	0.2	<0.3	<0.2	0.3	<0.2	<0.2	<0.3	<0.2
Bromoform	0.4	<0.1	0.3	<0.1	<0.1	<0.1	>40	ca40	50	0.3	<0.1	0.9	<0.1	13.8	30	<0.1	<0.1	<0.1
Toluene	0.2	<0.2	0.2	<0.1	<0.2	0.4	<0.1	0.2	0.2	<0.1	0.1	0.2	<0.1	0.2	0.2	<0.1	0.2	0.2
Chlorobenzene	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
1,4-dichlorobenzene	0.7	<0.2	<0.2	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.2	<0.2	0.4	<0.2	<0.3	<0.2	<0.2	<0.3
1,2-dichlorobenzene	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.6	0.2	<0.1	<0.1	<0.1	<0.1
Tetrachloroethylene	0.8	0.5	0.4	0.8	0.5	0.4	<0.2	<0.1	<0.1	0.5	<0.2	0.4	<0.2	<0.2	0.1	<0.2	0.1	0.1

TABLE G-1 - Cont.

Source	Montebello Forebay Wells												Imported Waters					
	1514A			1621MM			1620GG			1562E			Colorado River			State Project		
Target Compound µg/l	$UnCl_2$ Well	$UnCl_2$ Well	$UnCl_2$ Well	$UnCl_2$ Well	$UnCl_2$ Well	$UnCl_2$ Well	$UnCl_2$ Well	$UnCl_2$ Well	$UnCl_2$ Well	$UnCl_2$ Well	$UnCl_2$ Well	$UnCl_2$ Well						
Vinyl chloride	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1.0	<1	<1	<1.0
Methylene chloride	0.4	<0.2	<0.2	2.6	0.2	<0.2	1.3	<0.2	<0.2	<0.2	<0.2	<0.2	1.0	1.7	<0.2	0.7	<0.2	<0.2
1,1-dichloroethane	<0.1	<0.1	<0.1	<0.1	0.1	0.1	<0.1	1.0	0.4	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chloroform	<0.4	<0.4	<0.2	0.9	0.5	0.5	<0.4	<0.4	0.8	<0.4	<0.2	<0.2	19	9.6	24.0	<0.4	<0.4	0.2
1,2-dichloroethane	<0.2	<0.2	<0.2	<0.2	0.3	<0.2	0.2	0.7	0.6	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Carbon tetrachloride	<0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.4	<0.2	<0.1	<0.1	<0.1	<0.1
Bromodichloromethane	0.8	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	24	18	24.0	<0.1	<0.1	<0.1
Trichloroethylene	<0.1	0.8	0.7	<0.2	<0.2	<0.2	1.4	1.2	1.3	0.2	0.2	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Dibromochloromethane	<0.1	0.2	<0.1	<0.1	0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	21	20	20.0	0.1	<0.1	<0.1
1,1,2-trichloroethane	<0.2	<0.2	<0.2	<0.2	0.2	<0.2	<0.2	<0.1	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.1	<0.2	<0.2	<0.1
Benzene	<0.1	<0.3	<0.2	0.3	<0.3	<0.3	0.4	<0.3	<0.2	<0.3	<0.2	<0.3	<0.2	<1	<0.2	<0.2	<0.3	<0.2
Bromoform	<0.1	0.1	<0.1	<0.1	0.2	0.2	<0.1	0.1	0.6	0.2	0.1	<0.1	3.5	3.6	2.9	<0.1	0.3	<0.1
Toluene	<0.1	0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.2	<0.2	0.2	0.2	<0.2	0.8	<0.2	<0.2	0.2	<0.2
Chlorobenzene	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
1,4-dichlorobenzene	0.2	<0.2	<0.3	<0.2	0.4	<0.2	0.2	0.1	<0.3	<0.2	<0.3	<0.2	<0.2	0.2	<0.2	<0.2	<0.2	<0.2
1,2-dichlorobenzene	<0.1	<0.1	<0.1	<0.1	0.4	<0.1	<0.1	0.2	<0.1	0.2	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	0.2	<0.1
Tetrachloroethylene	0.2	0.2	0.2	<0.2	0.5	0.3	<0.2	1.0	1.0	0.5	0.4	0.4	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

TABLE G-1 - Cont.

Source	San Jose Creek WRP							Whittier Narrows WRP					Pomona WRP	
Target Compound µg/l	UnCl$_2$ 2°	Cl$_2$ 2°	UnCl$_2$ 2°	Cl$_2$ 2°	DeCl$_2$ 3°	DeCl$_2$ 3°	DeCl$_2$ 3°	UnCl$_2$ 2°	Cl$_2$ 2°	DeCl$_2$ 3°	DeCl$_2$ 3°	DeCl$_2$ 3°	DeCl$_2$ 3°	DeCl$_2$ 3°
Vinyl chloride	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	*	<1	<1
Methylene chloride	4.1	5.1	87	45	29.4	14	6.2	10.0	12.2	56	46.3	*	4.9	<0.5
1,1-dichloroethane	0.5	0.5	<0.1	<0.1	0.2	<0.1	<0.1	0.2	0.4	1.8	<0.1	<0.1	0.5	<0.1
Chloroform	4.6	7.7	2.6	36.5	13.8	16	7.1	3.2	8.8	84	5.1	4.9	8.2	5.8
1,2-dichloroethane	1.2	<1	<0.2	<0.2	1.6	<0.2	0.2	1.4	2.2	<0.2	0.5	<0.2	<0.2	0.3
Carbon tetrachloride	*	*	<0.1	<0.1	*	12	0.5	*	*	*	0.4	<0.1	<0.1	0.4
Bromodichloromethane	<0.1	0.3	<0.1	<0.1	0.4	0.1	1.7	<0.1	1.6	1.8	0.6	1.4	2.9	2.1
Trichloroethylene	8.0	8.9	0.6	0.5	8.0	0.2	<0.2	2.1	4.1	19.4	0.7	<0.2	0.3	<0.2
Dibromochloromethane	0.3	<0.2	<0.1	<0.1	0.2	<0.1	0.5	0.2	0.8	1.2	0.6	0.6	1.5	2.1
1,1,2-trichloroethane	0.9	<0.2	<0.2	<0.2	<0.2	<0.2	21	<0.2	<0.2	0.6	<0.2	<0.2	<0.1	<0.2
Benzene	1.2	0.5	2.9	0.3	2.2	0.6	<0.2	<0.2	0.7	<0.2	<0.2	<0.2	<0.2	0.2
Bromoform	0.6	0.2	<0.1	<0.1	4.8	<0.1	0.2	7.8	0.4	0.8	0.4	0.2	0.3	1.4
Toluene	1.5	1.3	<0.1	<0.1	0.2	<0.1	0.2	0.4	0.6	0.2	0.3	<0.2	0.1	<0.2
Chlorobenzene	0.3	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	<0.4	<0.1	<0.1	<0.1	<0.1
1,4-dichlorobenzene	2.5	3.1	3.1	2.1	4.6	2.7	2.0	4.0	4.6	10.2	1.9	2.1	1.4	0.2
1,2-dichlorobenzene	0.2	0.3	0.9	0.6	0.3	0.2	0.3	0.5	1.0	6.0	2.0	0.4	0.6	0.2
Tetrachloroethylene	6.2	5.8	<0.2	<0.2	3.2	<0.2	1.0	10.8	17.4	60	3.4	0.3	6.0	1.2

TABLE G-1 - Cont.

	Orange County & L.A. City Reclamation Plants							Surface Runoff								
Source	Orange County Water Factory 21				L.A./Glendale Water Reclamation Plant			L.A. River at Headworks			Rio Hondo River Forebay (Montebello Forebay)					
Target Compound µg/L	Cl_2 A.C.c/	Cl_2 A.C.	Cl_2 R.O.	UnCl_2 R.O.	Cl_2 3°	Cl_2 3°	Cl_2 3°	Dry Weather Runoff			Storm Water Runoff					
Vinyl chloride	<1	<1.0	<1.0	*	<1	<1.0	<1.0	<1	<1.0	<1.0	<1	<1.0	*	<1.0	<1.0	<1.0
Methylene chloride	2.1	0.7	0.3	*	18.7	5.5	4.4	0.6	0.2	2.4	0.4	1.6	*	<0.6	<0.6	0.8
1,1-dichloroethane	0.2	<0.1	<0.1	<0.1	0.2	0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	*	<0.1	<0.1	<0.1
Chloroform	>200	9.8	0.7	0.5	7.9	5.3	5.1	0.4	0.2	0.9	0.6	0.5	*	<0.2	<0.2	0.4
1,2-dichloroethane	<0.2	<0.2	<0.2	<0.2	1.2	0.6	0.2	<0.2	<0.2	0.4	<0.2	0.3	*	<0.2	<0.2	<0.2
Carbon tetrachloride	0.6	0.7	<0.1	<0.1	0.6	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*	<0.2	<0.1	<0.2
Bromodichloromethane	108	4.9	0.6	0.3	3.2	7.6	5.8	<0.1	<0.1	<0.1	<0.1	<0.1	*	<0.2	0.1	0.2
Trichloroethylene	<0.2	<0.2	<0.2	<0.2	1.1	0.4	1.0	<0.2	<0.2	<0.2	<0.2	<0.2	*	0.8	<0.2	0.8
Dibromochloromethane	61.5	2.2	0.6	0.3	2.9	5.6	6.6	<0.1	0.1	0.3	0.2	0.1	<0.1	<0.1	<0.1	<0.1
1,1,2-trichloroethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.1	<0.2	<0.2	0.1	<0.2	0.1	<0.1	0.2	<0.1	<0.1
Benzene	0.2	<0.2	<0.2	<0.2	<0.1	<0.2	<0.2	<0.2	0.3	<0.2	<0.3	0.2	*	<0.4	<0.4	<0.4
Bromoform	9.2	0.9	0.2	0.1	0.9	2.0	3.8	<0.1	<0.1	0.2	1.6	0.1	<0.1	<0.1	<0.1	<0.1
Toluene	0.2	<0.2	<0.2	0.4	<0.1	0.4	0.3	<0.2	<0.2	<0.2	0.2	0.5	<0.3	<0.3	<0.3	<0.3
Chlorobenzene	0.6	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
1,4-dichlorobenzene	0.2	<0.3	<0.3	<0.2	6.8	2.9	2.4	<0.2	<0.3	<0.2	1.2	<0.2	<0.2	<0.2	<0.2	0.3
1,2-dichlorobenzene	<0.1	<0.1	<0.1	<0.1	2.6	0.9	1.0	<0.1	<0.1	<0.1	1.3	<0.1	0.1	<0.1	<0.1	0.1
Tetrachloroethylene	0.6	1.2	<0.2	0.1	5.2	2.5	17.0	0.1	0.5	0.3	1.5	0.4	0.8	3.4	0.4	5.7

TABLE G-1 - Cont.

Source	Orange County Wells																	
	Yorba Linda #11			Anaheim #22			Anaheim #27			Anaheim #29			Talbert Barrier M-10			Talbert Barrier M-12		
Target Compound µg/L	Cl_2 Well			$UnCl_2$ Well			$UnCl_2$ Well			$UnCl_2$ Well			$UnCl_2$ Observation Well			$UnCl_2$ Observation Well		
Vinyl chloride	<1	<1	<1.0	<1	<1.0	<1.0	<1	<1	<1.0	<1	<1.0	*	<1	<1.0	<1.0	<1	*	<1.0
Methylene chloride	6.8	<0.2	<0.2	0.8	<0.2	<0.2	0.6	<0.2	<0.2	<0.2	<0.2	*	1.2	0.2	0.1	0.8	*	0.5
1,1-dichloroethane	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chloroform	0.9	0.5	0.3	<0.4	<0.2	<0.2	0.4	1.0	1.2	<0.4	<0.2	<0.2	4.0	1.4	0.7	1.8	4.9	3.5
1,2-dichloroethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Carbon tetrachloride	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Bromodichloromethane	4.2	1.5	1.6	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.0	0.3	<0.1	0.3	1.4	0.6
Trichloroethylene	<0.2	<0.2	<0.2	1.4	0.9	1.0	<0.2	<0.2	<0.2	3.7	2.3	1.9	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Dibromochloromethane	21	6.3	7.3	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	0.5	0.2	<0.1	0.2	0.7	0.3
1,1,2-trichloroethane	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Benzene	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Bromoform	33	21	29	0.2	<0.1	<0.1	0.9	0.2	0.3	-	<0.1	0.2	<0.1	<0.1	<0.1	<0.1	0.1	<0.1
Toluene	0.3	0.2	<0.2	0.2	<0.2	<0.2	0.3	0.2	<0.2	<0.1	<0.2	<0.2	0.3	<0.2	<0.2	0.7	<0.2	<0.2
Chlorobenzene	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
1,4-dichlorobenzene	<0.2	<0.3	<0.3	<0.2	<0.3	<0.3	<0.2	<0.3	<0.3	<0.2	<0.3	<0.3	<0.2	<0.3	<0.2	<0.2	<0.3	<0.2
1,2-dichlorobenzene	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	<0.1	<0.1	<0.1
Tetrachloroethylene	0.1	<0.1	<0.1	<0.1	<0.2	0.1	1.6	1.1	1.1	<0.1	<0.2	<0.1	0.2	<0.2	<0.1	0.5	<0.2	0.1

TABLE G-1 - Cont.

Source	L.A. City Department of Water & Power Wells					
	North Hollywood #5			Pollack Wells Collector		
Target Compound µg/L	$UnCl_2$ Well			$UnCl_2$ Wells		
Vinyl chloride	<1	<1.0	*	<1	<1.0	<1.0
Methylene chloride	*	0.1	*	1.5	0.8	<0.2
1,1-dichloroethane	<0.1	<0.1	*	2.3	0.3	1.3
Chloroform	3.2	1.4	1.7	0.5	4.1	0.5
1,2-dichloroethane	0.3	0.3	0.2	1.3	<0.2	0.5
Carbon tetrachloride	<0.1	0.1	<0.1	1.1	0.2	0.5
Bromodichloromethane	0.1	0.1	0.4	<0.1	3.9	<0.1
Trichloroethylene	0.9	27.0	14.4	6.7	1.6	1.6
Dibromochloromethane	<0.1	<0.1	<0.1	<0.1	1.2	<0.1
1,1,2-trichloroethane	<0.2	<0.2	<0.1	<0.2	<0.2	<0.2
Benzene	0.5	<0.2	<0.4	0.3	<0.2	<0.2
Bromoform	<0.1	<0.1	<0.1	<0.1	1.9	<0.1
Toluene	<0.2	<0.2	<0.3	<0.2	<0.2	<0.2
Chlorobenzene	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
1,4-dichlorobenzene	<0.2	<0.3	<0.2	<0.2	<0.3	<0.2
1,2-dichlorobenzene	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Tetrachloroethylene	0.1	1.7	1.6	10.0	2.4	5.7

a/ Summary of abbreviations used in Table G.1:
UnCl$_2$ = unchlorinated
Cl$_2$ = chlorinated
DeCl$_2$ = dechlorinated
2° = secondary effluent
3° = tertiary (filtered) effluent
A.C. = activated carbon effluent
R.O. = reverse osmosis effluent

b/ * = sample contaminated

c/ Sample not dechlorinated at time of sampling.

d/ Sample locations may be cross-referenced in Tables III-1, III-2, III-3.

e/ Discussion of these results may be found in Chapter IV, pg. IV-19 - IV-32.

TABLE G-2

NON-PURGEABLE TARGET ORGANIC RESULTS

G.2A Montebello Forebay Samples	Sample Number	Compound	Concentration (μg/L)
San Jose Creek WRP Secondary ($UnCl_2$)	1	DEHP	4.8
	19	aldrin	0.6
		DEHP	0.6
San Jose Creek WRP Secondary (Cl_2)	2	DEHP	9.5
	20	2,4,6-trichlorophenol	0.03
		2,4,5-trichlorophenol	0.05
		3,4,5-trichlorophenol	0.24
		2,3',5-trichlorobiphenyl	0.07
		2,2',4,4'-tetrachlorobiphenyl	0.08
		fluoranthene	0.11
		o,p'-DDT	0.05
		DEHP	0.7
San Jose Creek WRP Dual Media ($DeCl_2$)	5	DEHP	13
	18	aldrin	0.9
		DEHP	1.1
	59	1,2,4-trichlorobenzene	0.40
		2,4,6-trichlorophenol	0.74
		2,4,5-trichlorophenol	0.87
		pentachlorophenol	16
		phenanthrene	1.7
		DEHP	3.8
Whittier Narrows WRP Secondary ($UnCl_2$)	3	DEHP	3.2
Whittier Narrows WRP Secondary (Cl_2)	4	DEHP	11

TABLE G-2 Cont.

NON-PURGEABLE TARGET ORGANIC RESULTS

G.2A Montebello Forebay Samples	Sample Number	Compound	Concentration (μg/L)
Whittier Narrows WRP Dual Media ($DeCl_2$)	7	DEHP	6.1
	28	aldrin	0.6
		1,2,4-trichlorobenzene	0.04
		DEHP	2.3
	68	lindane	1.0
		DEHP	3.1
Pomona WRP Activated Carbon (Cl_2)	9	DEHP	1.4
	31	DEHP	0.9
Rio Hondo Storm Flow	40	2,4,6-trichlorophenol	1.9
		2,4,5-trichlorophenol	1.7
		2,3,4-trichlorophenol	1.8
		3,4,6-trichlorophenol	0.7
		2,3,6-trichlorophenol	6.7
		pentachlorophenol	6.8
		fluoranthene	3.3
		DEHP	48.8
	80	phenylacetic acid	4.7
		DEHP	45.2
	87	lindane	1.4
		DEHP	69.7
	88	phenylacetic acid	1.1
		simazine	6.6
		atrazine	3.9
		phenanthrene	0.3
		DEHP	21.6
	89	phenylacetic acid	2.4
		simazine	1.5
		atrazine	1.3
		phenanthrene	0.4
		DEHP	81.5
	90	phenylacetic acid	16.4
		simazine	3.6
		atrazine	3.1
		DEHP	48.9

TABLE G-2 Cont.

NON-PURGEABLE TARGET ORGANIC RESULTS

G.2A Montebello Forebay Samples	Sample Number	Compound	Concentration (μg/L)
Colorado River Water	32	DEHP	2.9
	43	Dieldrin	0.4
		o,p'-DDT	0.1
		DEHP	13.3
	86	DEHP	167
State Project Water	33	DEHP	0.3
	42	DEHP	0.3
	85	DEHP	38.1
Well 1580J (UnCl$_2$)	6	DEHP	3.2
	34	DEHP	0.2
	49	phenylacetic acid	2.1
		atrazine	0.9
		DEHP	18.6
Well 1566A (UnCl$_2$)	8	DEHP	35
	35	DEHP	0.2
	50	DEHP	33.5
Well 2907 (Cl$_2$)	10	DEHP	5.7
	39	DEHP	3.3
	51	simazine	1.7
		atrazine	0.9
		DEHP	8.4
Well 1591H (UnCl$_2$)	11	DEHP	3.4
	22	DEHP	0.6
	52	atrazine	0.8
		DEHP	59.1

TABLE G-2 Cont.

NON-PURGEABLE TARGET ORGANIC RESULTS

G.2A Montebello Forebay Samples	Sample Number	Compound	Concentration ($\mu g/L$)
Well 2958A (Cl_2)	12	DEHP	1.6
	21	DEHP	0.2
	56	DEHP	2.0
Well 2947Q ($UnCl_2$)	15	DEHP	0.8
	48	DEHP	4.0
	54	2,4,6-trichlorophenol	1.5
		DEHP	1.9
Well 1514A ($UnCl_2$)	16	DEHP	0.2
	44	DEHP	4.8
	55	DEHP	5.2
Well 1621MM ($UnCl_2$)	17	ND[a]	0.1
	45	DEHP	0.5
	53	2,4,6-trichlorophenol	0.5
		DEHP	34.6
Well 1620GG ($UnCl_2$)	23	DEHP	0.2
	46	DEHP	7.8
	57	DEHP	4.1
Well 1562E ($UnCl_2$)	41	DEHP	0.2
	47	3,4,5-trichlorophenol	0.7
		pentachlorophenol	0.8
		atrazine	0.5
		phenylacetic acid	3.1
		DEHP	8.2
	58	DEHP	0.65

TABLE G-2 Cont.

NON-PURGEABLE TARGET ORGANIC RESULTS

G.2B San Fernando Basin Samples	Sample Number	Compound	Concentration (μg/L)
LA/Glendale WRP Dual Media (Cl_2)	14	DEHP	1.4
	71	1,2,4-trichlorobenzene	3.3
		2,4,6-trichlorobenzene	0.6
		2,4,5-trichlorobenzene	0.2
		pentachlorophenol	7.6
		DEHP	4.0
	84	1,2,4-trichlorobenzene	0.9
		2,4,6-trichlorophenol	0.9
		2,4,5-trichlorophenol	0.2
		pentachlorophenol	13
		lindane	0.6
		DEHP	19.7
Los Angeles River at Headworks Spreading Grounds - Dry Weather Runoff	37	fluoranthene	0.01
		DEHP	11.5
	69	DEHP	4.1
	83	1,2,4-trichlorobenzene	0.4
		2,3,5 trichlorophenol	0.4
		2,4,6-trichlorophenol	0.3
		2,4,5-trichlorophenol	0.6
		2,3,4-trichlorophenol	0.4
		2,3,6-trichlorophenol	0.4
		3,4,5-trichlorophenol	2.7
		phenylacetic acid	9.2
		simazine	8.5
		atrazine	3.4
		DEHP	6.8
Pollack Wells Collector ($UnCl_2$)	38	DEHP	0.6
	70	DEHP	0.6
	81	simazine	1.5
		atrazine	0.6
		DEHP	9.4

TABLE G-2 Cont.

NON-PURGEABLE TARGET ORGANIC RESULTS

G.2B San Fernando Basin Samples	Sample Number	Compound	Concentration ($\mu g/L$)
North Hollywood Well #5 ($UnCl_2$)	36	DEHP	0.2
	72	DEHP	0.6
	82	DEHP	2.7
G.2C Orange County - Talbert Gap and Anaheim Forebay			
Water Factory 21 Activated Carbon (Cl_2)	13	DEHP	0.4
	65	DEHP	2.9
Water Factory 21 Reverse Osmosis ($UnCl_2$)	64	phenanthrene	0.1
		DEHP	0.9
	77	DEHP	1.2
Talbert Barrier Observation Well M-10 ($UnCl_2$)	29	DEHP	0.2
	66	DEHP	2.9
	78	phenanthrene	0.06
		DEHP	3.5
Talbert Barrier Observation Well M-12 ($UnCl_2$)	30	DEHP	0.4
	67	DEHP	6.9
	79	DEHP	15.9
Yorba Linda Well #11 (Cl_2)	24	DEHP	0.3
	60	1,2,4-trichlorobenzene	0.2
		2,4,6-trichlorophenol	0.4
		simazine	7.9
		atrazine	1.1
		DEHP	0.5
	73	simazine	5.8
		atrazine	0.9
		DEHP	0.4

TABLE G-2 Cont.

NON-PURGEABLE TARGET ORGANIC RESULTS

G.2C Orange County - Talbert Gap and Anaheim Forebay	Sample Number	Compound	Concentration (μg/L)
Anaheim Well #22 ($UnCl_2$)	26	DEHP	0.6
	63	DEHP	1.2
	76	DEHP	0.2
Anaheim Well #27 ($UnCl_2$)	25	ND	0.05
	61	simazine	5.7
		DEHP	1.7
	74	simazine	3.2
		DEHP	3.3
Anaheim Well #29 ($UnCl_2$)	27	DEHP	0.4
	62	ND	0.02
	75	DEHP	0.4
G.2D Sample Blanks			
19 Blank		DEHP	0.04
21 Blank		DEHP	0.06
39 Blank		DEHP	0.5
48 Blank		DEHP	1.6
56 Blank		DEHP	1.9
New Resin Blank		ND	0.05
74 Blank		ND	0.05
91 Blank		ND	0.05

a/ ND = not detected; detection limits shown are for DEHP.

APPENDIX H
TOXICOLOGY SCREENING METHODS

AMES SALMONELLA MICROSOME MUTAGEN ASSAY

I. INTRODUCTION

The *Salmonella* microsome mutagen assay is a bacterial screening assay for the detection of frame-shift and base-pair substitution type organic chemical mutagens. The test was developed by Dr. B. N. Ames, and methods used in the Health Effects Study followed recommendations published by Ames (H-1) for the plate-incorporation assay. The test utilizes specially cultured strains of histidine-dependent *Salmonella* bacteria which, when exposed to a mutagen in a histidine deficient medium, mutate (or revert) to histidine independence. The number of bacterial colonies which result relate directly to the number of mutations induced by the chemical. Since the *Salmonella* test strains do not possess the compliment of enzymes found in mammalian systems, and since several classes of mutagens are known to require enzyme activation before they become biologically active, Ames expanded the scope of the bacterial assay by providing for the addition of a mammalian enzyme mix (H-2). This mix is the S9 microsome fraction from liver homogenates (in this study, Aroclor-induced rat liver homogenate). The Ames protocol calls for three different concentrations of S9 to be used at each sample dose tested, a procedure followed for all dose-response experiments in this study. However, in about 70 percent of the tests, the 50 µl dose of S9 proved to be sufficient for determining test outcome. Only in the most polluted samples did the additional S9 have an effect--usually to detoxify the test mixture.

It is believed that most chemical carcinogens are also mutagens, that is, they cause heritable change in genetic cells, specifically in the genetic codes carried by DNA. In tests with more than 300 chemicals, Ames (H-3) has demonstrated that the *Salmonella* microsome mutagen assay is approximately 90 percent effective in detecting known animal carcinogens and discriminating against non-carcinogens. The test has become a very sensitive means of detecting the presence of *presumed* carcinogens.

There are many published applications of the assay in food, cosmetics, air, and water; these were reviewed in Chapter IV. For the Health Effects Study, only two test strains were routinely used, TA98 and TA100. These strains have been reported as the most effective for detection of waterborne mutagens (H-4). For some specific chemical tests, two other strains were also employed TA1535 and TA100 FRI (nitro reductase-deficient TA100).

The desire to repetitively test fractions from mutagenic residues lead to a modification of the plate incorporation assay in order to increase sensitivity and to conserve sample residue. The modification involved short term "incubation" of the sample with the test strains in tubes prior to application to the test plate. This method was not used for quantitative dose-response experiments, but only for experiments where a positive/negative response or internal comparison was required.

Positive and negative controls were run with every experiment as recommended by Ames. In situations where the results for the controls were outside of published acceptable ranges, the entire experiment was repeated. Test scoring was accomplished by use of an ARTEK automatic colony counter interfaced to a Texas Instruments Model 59 programmable calculator. Performance of the automatic counter was checked by manual scoring at various intervals.

II. METHOD OUTLINE

A. Media and Reagents
   1. Vogel Bonner Salts
   2. Glucose Solution
   3. Top Agar
   4. Growth Medium
   5. Vogel Bonner Agar
   6. S9 Reagents
   7. S9 Mix
   8. Histidine Biotin Solution

B. Growing Salmonella Tester Strains
   1. Routine Culture Growth
   2. Re-isolation of Stock

C. Verification of Genetic Markers
   1. Histidine Requirement
   2. rfa Mutation
   3. R Factor
   4. uvrB Deletion

D. Mutagenesis Testing

   1. Plate Incorporation Test
      a. Negative controls
      b. Positive controls
      c. Sterility controls
      d. Procedure
   2. Tube Assay

E. Controls Protocol
   1. Negative Controls
   2. Positive Controls

III. METHODS

A. Media and Reagents

1. Vogel Bonner Salts

Prepare 10x Vogel Bonner salts by adding the following ingredients to deionized water (DI) in the order listed. Allow each ingredient to dissolve completely before adding next ingredient.

$MgSO_4 \cdot 7H_2O$	12	g
Citric acid $\cdot$ H_2O	120	g

K_2HPO_4 (powder)	600 g
$NH_4H_2PO_4$	158.4 g

Add the reagents to approximately 3000 mL H_2O while stirring, then bring volume to 6000 mL.

After ingredients are dissolved, dispense the salt solution in 6 oz. Brochway bottles at 120 mL each and autoclave at 15 lbs/60 min.

2. Glucose Solution

Weigh out 200 g dextrose (powder is light; should be large amount). Add powder to 300 mL DI H_2O while water is stirring; heat to dissolve. Dispense in 500 mL serum bottle and autoclave at 15 lbs/15 min.

3. Top Agar 0.6%

The volume needed will depend on the size of the assay. Generally, make 700 mL by adding 4.2 g agar (Difco) and 3.5 g NaCl to 700 mL DI H_2O, bring to boil and autoclave at 15 lbs/15 min. Cool to 48°C in small waterbath and add 1 mL/100 mL working solution Histidine-Biotin (see A.8).

4. Growth Medium

Use TSB for growing out cultures. Do not use nutrient broth. Prepare enough for several weeks of testing. Dispense broth into narrow mouth milk dilution bottles at 30 mL per bottle. Autoclave 15 lbs/15 min.

5. Vogel Bonner Agar

Prepare agar in 3000 mL batches using 4 L glass beakers. One batch is sufficient for about 120 plates. Add the following reagents:

10x Vogel Bonner salts	300 mL
Agar (BBL)	45.1 g
DI H_2O	2650 mL

Bring to boil and autoclave at 15 lbs/15 min. Allow agar to cool to 60°C and add 67.4 mL dextrose solution. Allow agar to cool further to 40-50°C (do not use waterbath; agar will cool unevenly). Dispense into petri dishes at 20 mL each using automatic pipetter.

6. S9 Reagents

   a. NADP (TPN coenzyme II). Prepare a stock by dissolving 1 g in 30 mL DI H_2O. Filter sterilize using 0.22 μM MF. Store at -20 C.

b. Glucose-6-phosphate, 1.0 M. Add 10.0 g G-6-P to 60 mL DI H_2O. Filter sterilize using 0.22 MF. Store at -20°C.

c. MgCl, 0.4 M, 3.81 g/100 mL
KCl, 1.65 M, 12.3 g/100 mL
Autoclave at 15 lbs/15 min. Store at -20°C.

d. Na_2HPO_4, 0.2 M, 14.20 g/500 mL. Check final pH (should be 7.4). Autoclave 15 lbs/15 min. Store at -20°C.

7. S9 Mix

Prepare S9 mix in 500 mL batches and distribute in 50 mL quantities in milk dilution bottles.

	S9-50 µL	S9-100 µL	S9 mix
NADP	50 mL	50 mL	50 mL
Glucose-6-Phosphate	5 mL	5 mL	5 mL
MgCl	10 mL	10 mL	10 mL
KCl			
Na_2HPO_4	250 mL	250 mL	250 mL
DI-H_2O	135 mL	85 mL	185 mL
Amt. 1 Bottle	45 mL	40 mL	50 mL

Filter sterilize through 0.2 µM MF before dispensing S9 mix into milk dilution bottles. Store at -20° C. On the day of assay, thaw out appropriate number of bottles and add S9 just prior to use. Add 5 mL for S9-50 and 10 mL for S9-100. Do not thaw out S9 completely but just enough to facilitate removal. Keep S9 on ice during entire assay.

8. Histidine-Biotin

Final concentration of HIS/BIO is 0.05 mM in 2 mL top agar.

a. Stock solutions: Histidine, 100 mM 209.6 mg/100 mL H_2O
Biotin, 10 mM 24.4 mg/100 mL H_2O

b. Working solution: 89 mL DI H_2O
10 mL 10 mM biotin
1 mL 100 mM histidine

Filter sterilize working solution; store at -20°C.

B. Growing Salmonella Tester Strains

1. Routine Culture Growth

Keep all stocks at -70°C. On the day before the assay scrape the top of the frozen culture with a sterile pipet and inoculate TSB. Incubate at 37°C on a shaker platform. Maximize aeration of broth by keeping lid loosened and taped to bottle. Incubate cultures 16 hours only, then refrigerate until use. Return frozen stocks to -70°C as soon as possible.

2. Reisolation of Stock

When stocks become contaminated or spontaneous reversion is abnormally high, stocks must be reisolated. Streak directly to agar from frozen stock (not from outgrowth medium). Grow out for 12-16 hours and grow up 6 isolates in TSB. After 16 hours dispense culture in 2 mL amounts in sterile disposable plastic tubes. Add 0.2 mL sterile DMSO and quick freeze in acetone/dry ice bath. Verify markers on 6 isolates (see section C). Retain satisfactory isolates, discard others.

C. Verification of Genetic Markers

1. Histidine Requirement (all strains)

Streak culture on minimal agar plates containing 100 μL 0.1 M HIS, 0.5 biotin per plate. Also streak minimal agar as control.

2. rfa Mutation (all strains)

Ingredients:

crystal violet 1 mg/mL
trypticase soy agar (TSA)
top agar

Mix 100 μL of test culture with 2 mL top agar and pour over TSA plate. After agar is solidified add paper disc (no. 1 Whatman, cut with hold punch) saturated with crystal violet solution. Incubate 24 hours at 37°C. All strains should exhibit a clear zone of inhibition around the disc. The zone should be about 14 mm in diameter.

3. R Factor (TA100, TA98, TA100-FRI)

Ingredients:

TSA plates
ampicillin sensi-discs 10 μg

Streak cultures on TSA plates using sterile cotton swabs. Place disc on center of plate and incubate for 24 hours at 37°C.

4. uvrB Deletion (all strains)

Ingredients:

TSA plates
germicidal lamp GE15W

Streak cultures on TSA plates using cotton swabs. Irradiate half the plate with the lamp at 33 cm. Irradiate TA98, TA100 for 8 seconds, TA 1535 for 6 seconds. Incubate plates 24 hours at 37°C.

D. Mutagenesis Assay

1. Plate Incorporation Test

a. Negative controls

Set up controls for solvent (DMSO), buffer, S9 used (S9-50, S9-100) and no reagent control. Do two replicates at the start of the assay, and two at the end. The TI 59 calculator program is keyed to accept controls in a set order; label plates accordingly (see control protocol).

b. Positive controls

Generally, when TA98 and TA100 are used, four positive mutagens are used. All mutagens are prepared in 2 mL DMSO and 100 μL is delivered per plate.

TA98: 2-aminofluorene (AMF) 100 μg/mL
aflatoxin B_1 (AB-1) 10 μg/mL
4-nitroquinoline-N-oxide (4NQO) 10 μg/mL
daunomycin (DAUNO) 100 μg/mL

TA100: AMF 1 μg/mL
AB-1 10 μg/mL
methyl methane sulfonate (MMS) 20 μL/mL
sodium azide (NaN_3) 1 μg/mL

Positive controls are also keyed to TI 59 program and are labeled numerically (see control protocol).

c. Sterility controls

Five single sterility controls are set

d. Procedure

Materials needed:

minimal agar plates
top agar 2 mL/plate
tester strain, overnight broth culture 100 μL/plate
S9 mix and S9 at 50 μL/plate
sample to be tested in DMSO
for four dose 200, 100, 50, 25 μL need 4.5 mL sample
for three dose 200, 100, 50 μL need 4.3 mL sample

Maintain top agar at 45°C in waterbath. Add 100 μL tester strain, followed by 50 μL S9 or S9 mix. Add sample last. Vortex the mixture and pour over minimal agar plates. The entire procedure should take less than 20 seconds.

Use separate containers for S9 and buffer for each strain used to avoid cross contamination of cultures. As soon as plates are hard, incubate plates in the dark, upside down for 48 hours at 37°C.

2. Tube Assay

In this modified method, all sample dilutions, if any, are made before adding reagents directly to the tube containing the sample. The maximum sample volume possible is 1.5 mL per plate. The maximum amount of DMSO + acetonitrile tolerated is 300 μL.

Maintain top agar in a waterbath at 48 C. Add 2 mL agar directly to sample tube followed by the tester strain and the S9 mix. The S9 mix and tester strain can be combined so that 600 μL of the S9 bacterial mixture contains 500 μL S9 mix and 100 μL tester strain. Pour entire mixture over minimal agar plates and incubate right side up for 24 hours, then invert plates for an additional 24 hours.

E. Ames Test Control Protocol

1. Negative Controls. Two plates per control, at beginning and end of assay.

TA 98		TA 100	
K1	Buffer	K4	Buffer
K2	S9-100	K5	S9-100

K3	S9-50	K6	S9-50
K7	DMSO	K9	DMSO
K8	No rgt	K10	No rgt

2. Positive Controls. Two plates each at end of assay.

TA 98				TA 100			
Pk 1	2-AMF	+	Buffer	Pk 1	2-AMF	+	Buffer
Pk 2	2-AMF	+	S9-100	Pk 2	2-AMF	+	S9-100
Pk 3	2-AMF	+	S9-50	Pk 3	2-AMF	+	S9-50
Pk 4	AB-1	+	Buffer	Pk 4	AB-1	+	Buffer
Pk 5	AB-1	+	S9-100	Pk 5	AB-1	+	S9-100
Pk 6	AB-1	+	S9-50	Pk 6	AB-1	+	S9-50
Pk 7	4NQO	+	S9-100	Pk 7	MMS	+	Buffer
Pk 8	DAUNO	+	Buffer	Pk 8	NaN_3	+	Buffer

IV. PRECISION ANALYSIS OF POSITIVE CONTROLS

While the repeatability of sample assays after storage was discussed in Chapter IV and Appendix I, some controlled estimate of precision using known mutagens was desirable in order to better understand the relationships of sample mutagenicity determined in separate experiments. This was approached by randomly selecting eleven sets of controls, from a body of several hundred sets, for five mutagens used routinely as positive controls on TA98 and TA100, with and without S9 enzyme activation. Statistical parameters were determined for each, and are shown in Table H-1.

In terms of biological tests, the precision was fair to good on both strains over time except, perhaps, when the net revertants were close to background reversion. In this case, a fluctuation of 50 to 100 percent may be expected. This would imply that for samples with quite low potencies (at or near a net reversion rate equal to background), differences in revertants/plate would have to be about 1.5 to 2.0 times for the samples to be presumed to be really of different potencies (95 percent confidence level). However, as reversion rates increase, the required differences become relatively smaller.

These percent relative standard deviation ranges may be used to estimate the similarity (or magnitude of difference) in potencies of the various sample types presented in Chapter IV, Table IV-15.

TABLE H-1

PRECISION ANALYSIS OF POSITIVE CONTROLS

TA 98 Statistical Parameters a/

Compound	N	x	s	T	95% C.L.	% rsd
2-AMF	10	27	± 20	1.90	± 12	60
2-AMF + S9-50	10	950	±180	1.46	±110	12
2-AMF + S9-100	10	920	±200	1.77	±120	13
Daunomycin	8	100	± 39	2.01	± 28	28
AB-1 + S9-50	9	1300	±500	2.02	±330	25
AB-1 + S9-100	10	1200	±710	1.56	±440	37
4-NQO + S9-100	9	340	±180	1.89	±120	35

TA 100 Statistical Parameters a/

Compound	N	x	s	T	95% C.L.	% rsd
2-AMF + S9-50	9	450	±160	1.80	±110	24
2-AMF + S9-100	8	390	±150	1.89	±100	25
AB-1 + S9-50	10	770	±460	1.60	±290	38
AB-1 + S9-100	10	980	±500	1.46	±310	32
NaN_3	10	480	±270	1.75	±160	33
MMS	10	800	±290	1.65	±180	23

a/ Statistical Parameters are:
N = number of experiments,
x = average number of revertants per plate at given dose,
s = standard deviation (revertants),
T = Student's T Test,
95% C.L. = 95% confidence level of test variance (revertants),
% rsd = relative standard deviation at 95% C.L.

MAMMALIAN CELL TRANSFORMATION ASSAY METHODS AND RESULTS

I. INTRODUCTION

Mammalian cell transformation assays were conducted by the Comprehensive Cancer Research Center at the University of Southern California (USC). Dr. Sukdeb Mondal, M.D., and Dr. Charles C. Heidelberger, Ph. D., were the principle and co-principle investigators, respectively. Part-way through the study, Dr. Mondal left the Research Center, and Dr. Heidelberger assumed the role of principle investigator. Researchers Pearl MacRay, Bruce McKay, and Eric von Hofe participated under the direction of the principle investigators.

This particular assay was pioneered by Dr. Heidelberger and his associates, and has been used as a research tool in investigations of mechanisms of carcinogenesis in a number of applications (H-5 - H-11). The advantages of studying carcinogenic events in a well controlled system, free from host influences, has engendered the development of several model cultured cell systems in which malignant transformations of affected cells can be quantitatively investigated. At the beginning of the Health Effects Study, the cell systems most widely used were: hamster embryo fibroblasts; BALB/3T3 mouse embryo fibroblasts; C3H/10T1/2 mouse embryo fibroblasts, and rat embryo fibroblasts.

The C3H/10T1/2 cell line was chosen for study because of the proximity of the USC group to the study area and the degree to which the test system had been evaluated for known carcinogens and promoting agents.

II. DISCUSSION

Initially, each sample was to be tested for cellular toxicity (inhibition of cell plating efficiency) at different doses in order to determine LD_{10}, LD_{50}, and LD_{90}. Carcinogenicity was to be tested at three doses, initiating action at one dose in replicate using 12-O-tetradecanoyl-phorbol-13 acetate (TPA) as the promotor, and promoting action at one dose in replicate using 3-methylcholanthrene (MCA) at a sub-effective level as initiator.

Because the test system had not been used on unknown complex mixtures isolated from water residues, the development of acceptable assay protocols was a major unknown in successful application of the assay. The first obstacle encountered was difficulty in eliciting cytotoxicity at dose levels (of solvent containing residue) which were compatible with growth of the cells. A misunderstanding between the contractor and principle investigator regarding the approximate amounts of residue required in the test lead to too low of an organic carbon (TOC) dosage in initial cytotoxicity tests as seen in Table H-2. However, it was deemed possible by the investigator to test transforming activity in five of the first nine samples at a toxic level provided that the maximum solvent/residue dose was used. Subsequently, it was decided by the investigator to test the remaining residues at the maximum solvent dose allowable and use relative plating efficiency as a measure of cytotoxicity. These data are shown in Table H-3 for the calculated TOC residue dose, along with the transformation results.

It can be seen from Table H-2 that only ten of the samples were ultimately assayed for transforming ability at even a mildly toxic dose, such that these

TABLE H-2

CYTOTOXICITY OF SAMPLES TO C3H/10T1/2 CELLS

Sample Number	Dose, μg Total Organic Carbon/plate (test result) [a],[b]					
17	0.1(-)	1.0(-)	10(+)	N[c]	N	N
18	0.06(-)	0.6(-)	6(-)	12(-)	24(-)	60(-)
18-F1[d]	0.04(-)	0.4(-)	4(-)	8(-)	16(-)	40(-)
18-F2[e]	0.08(-)	0.8(-)	8(-)	16(-)	32(-)	81(-)
40	28(+)	56(++)	140(+++)	N	N	N
41	31(-)	62(-)	153(+++)	N	N	N
43	26(-)	52(-)	133(-)	N	N	N
44	13(-)	26(+)	67(+++)	N	N	N
45	3(+++)	6(+++)	13(+++)	N	N	N

[a] Test Results:

(-)	no toxicity observed,
(+)	0-25% cells killed,
(++)	25-50% cells killed,
(+++)	>50% cells killed.

[b] Positive control 3-MCA (1 μg/mL).
[c] N = not tested.
[d] F1 = Fraction one of Sample No. 18.
[e] F2 = Fraction two of Sample No. 18.

TABLE H-3

RESULTS OF TRANSFORMATION EXPERIMENTS

Sample Number	Dose (μg TOC)	RPE(%)[a]	# Type II Foci/ # Dishes Tested	# Type III Foci/ # Dishes Tested
CH_3CN	0.5%	100	0/20	0/20
DMSO	0.5%	100	0/20	0/20
6	10	114	0/17	0/17
8	4	82	0/16	0/16
10	7	N[b]	0/16	0/16
17	10	72	0/16	0/16
18	60	91	0/14;1/16	0/14;0/16
18-F1[c]	40	101	0/16	0/16
18-F2+3[d]	81	106	0/18	0/18
20	252	N	0/18	0/18
21	25	N	0/18	0/18
22	73	N	0/18	0/18
23	81	100	0/10	0/10
28	203	125	0/6	0/6
31	132	82	2/19	0/19
40	140	96	0/15	0/15
41	153	104	0/11	0/11
42	234	129	0/8	0/8
43	133;400	89	3/10;0/18	0/10;0/18
44	67	96	1/11	0/11
45	13	82	0/15	0/15
46	81-102	107	0/9	0/9
47	40	128	0/6	0/6
48	20	114	0/11	0/11
49	199	96	0/13	0/13
50	40	107	0/9	0/9
51	98	98	0/7	0/7
3-MCA	1 μg/mL	59	N	32/21
3-MCA	1 μg/mL	99	12/20	10/20
3-MCA	1 μg/mL	107	6/12	14/12

a/ RPE = Relative plating efficiency.
b/ N = not reported.
c/ F1 = Fraction one of Sample No. 18.
d/ F2+3 = Fractions two plus three of Sample No. 18.

results are not considered definitive, but rather preliminary. For definitive results, samples are usually assayed over a wide cytotoxic concentration range. Four of the ten samples exhibited a few type II foci, which are known to induce malignant tumors 50 percent of the time when injected into syngenic mice. No type III foci were observed (80 percent of which induce tumors). Sample No. 18, which was negative when first tested at a 60 μg TOC dose, had one dish with a type II focus when retested at a 24 μg dose. Sample No. 43, which elicited three type II foci in ten dishes at a 133 μg dose, did not transform any of 18 dishes at a 400 μg dose. This quantitative variability and low incidence of transformed foci suggests that the samples tested may have slight genotoxic effects in the standard transformation assay. There are some false negatives in the standard C3H1DT1/2 transformation test, and the assay is presently being made more sensitive by various modifications.

III. METHODS

Detailed procedures of the cytotoxicity and transformation assays are outlined below. Included are culturing, transferring, seeding, and scoring steps. All assays used ten or more cell dishes per dose, and 3-methylcholanthrene was used as a positive control for both RPE and transformation assay. Residue portions up to 50 percent of the total sample residue collected for a given sample were submitted for assay in DMSO, CH_3CN, or a known ratio of the two solvents. Doses were originally determined by rough estimate of residue recovery; subsequently, values were recalculated from individual sample TOC recovery in the concentration step. All test outcome data presented in this Appendix were taken from progress reports submitted by USC.

IV. PROCEDURES

A. General cell carrying procedure for 10T 1/2 fibroblast.

Stocks are grown in 25 cm T-flasks; medium of BME, with 10% Fetal Calf Serum (FCS) stored in 5% CO_2 incubator, 37°C.

B. Transferring Procedure (stocks):

1. Aspirate medium.
2. Rinse with PBS (this step removes serum, which is a trypsin inhibitor).
3. Add 2 mL of 0.1% trypsin, put back inside incubator and keep for 5 min. at 37°C; longer exposure to trypsin reduces the plating efficiency.
4. Take out and look at cells under microscope to make sure they are coming off flask.
5. Once cells are off, add more than twice as much medium plus 10% serum (4 mL).
6. Spin cells 10 min. at 600xg, aspirate off media. Add 10 mL of medium (plus 10% FCS) and resuspend cells.
7. Take an aliquot (1 mL) of this, dilute with 9 mL 0.1% saline, and count with Coulter counter.
8. Reseed $2x10^4$ cells/5 mL in 25 cm T-flask. Media change on day 9. Transfer on day 10.

C. Fixing and Staining Dishes

0.9% Saline and phosphate buffer, 5% Giemsa; Giemsa comes in concentrated solution: dilute 50 mL Giemsa and 50 mL buffer with 400 mL DI H_2O.

1. Aspirate medium off gently.
2. Rinse gently with 0.9% saline once.
3. Aspirate saline.
4. Fix plates with 100% methyl alcohol for 10 min. or longer.
5. Stain with Giemsa for 20 min. or longer.
6. Aspirate giemsa stain off.
7. Wash with tap H_2O once to remove excess stain.

D. Seeding Cells from Stocks for an Experiment

Stocks: One T-25cm^2 flask should be media changed on day 9 and used on day 10. It is a good policy to leave one T flask behind with unchanged medium on day 9, in case the transfer is contaminated.

1. Aspirate medium.
2. Wash with PBS. Add on side opposite the cell layer side.
3. Swirl gently, aspirate PBS off.
4. Add 2 mL of 0.1% trypsin.
5. Flame and put caps loosely on. Incubate for 5 min. Make sure to stop trypsin action when cells are just about to come off. Check with microscope to see if cells are coming off.
6. Add a volume of BME with 10% FCS which is more than twice the volume of the trypsin added. This stops action of trypsin at this point.
7. Centrifuge for 10 min. at 600xg.
8. Resuspend cells sterily in 5 mL BME plus 10% FCS for each 25 cm^2 T-flask trypsinized.
9. Aliquot 1 mL, add 9.0 mL PBS, and count on Coulter counter. Setting at CC is 4 for aperture, 4 for amplitude and 15 for threshold for 10T 1/2.
10. For mutation assay seed 10 plates at 10^5 cells/mL in 10 mL of medium per 100 mm plate.
11. For transformation assay seed plates at 2 x 10^3 cells/5 mL, 60 mm dish.
12. For cytotoxicity, seed at 200 cells/5 mL, 60 mm dish.

E. Toxicity Test: Inhibition of Colony-Forming Ability

1. Seed 200 cells/60 mm plate in 5 mL medium.
2. Let cells recover for 24 hours.
3. Add sample dose. If sample is insoluble in PBS, take it up in concentrated 1:1 acetonitrile/DMSO and add back to media such that final concentration of solvent mixture is 0.5% or less. Run solvent control.

5. Fix, stain and count colonies on day 10, post-seeding.

F. Data Collection and Processing: Toxicity Test

1. Number of colonies in control is X.
2. Number of colonies in treated dishes is Y.
3. Y/X = relative plating efficiency or survival (S) fraction. Plot on semi log paper, log (S) versus linear dose.

G. Transformation Assay

1. Seed 30 dishes per point with 2 x 10^3 cells/5 mL medium per 60 mm dish for transformation, 5 dishes at 200 cells for plating efficiency.
2. Let them recover 24 hour.
3. Add sample for 48 hours.
4. Remove carcinogen-containing medium.
5. Add new media without sample.
6. Media change cells every four days until confluent, then once a week after that.
7. Six weeks after treating cells with sample, fix and stain the dishes.
8. Fix and stain plating efficiency dishes 10 days after setting them up.

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APPENDIX I

RESULTS OF AMES ASSAYS OF TOTAL RESIDUES AND REVERSED-PHASE FRACTIONS

NOTES ON MUTAGENICITY DATA

Tabulated results in Table I-1 are shown as Revertants/Liter (Rev/L) for each tester strain, with and without S9 enzyme activation. The table is arranged by sampling site in each of the study areas, whereas graphical results are presented in numerical order. For results of S9 experiments, the Rev/L shown is the highest number from the three different S9 doses used (this was almost always the 50 µL dose). For graphical results, only mutagenic samples are plotted, and only positive results are shown; absence of an experiment (e.g. no plot for TA100+S9) in a given graph indicates that no mutagenicity was observed for that sample with that strain. Coordinates used are revertants/plate vs residue dose. The amount of residue tested for each sample was the same (10%), and the volume of residue tested at each dose represents similar proportions of sample, from sample to sample. Therefore, rough graphical comparisons of potencies from sample to sample are possible. For repeated tests and fractionation experiments, the percent of sample and residue concentration were adjusted so that doses tested were comparable to the original assay. Therefore, repeatability may be assessed by comparing the original results and the repeat results for a given sample. Results from fractions are directly comparable to those for the respective whole residues, and fraction results may be added together and compared to the whole residue to estimate additivity, inhibition, or synergism. The flattening in slope of some of the curves in most samples indicates that residues were usually being tested in a range having some cytotoxic effect on the tester strains, even though cytotoxicity was not routinely determined.

Calculation Notes

Average net revertants for a given dose were calculated as simple numerical averages for replicate doses, and were termed revertants/plate for calculation of REV/L. For graphical plots in Figure I-1, the average revertants/µL sample dose were plotted directly.

Revertant/L calculations were derived as follows:

(i) $D = A(B/C)$

(ii) $G = \frac{E-F}{D}$

where

A = volume of water sample concentrated times percent of sample Ames tested;

B = volume of residue dosed per plate;

C = volume of DMSO in which sample was dissolved;

D = volume of orginal water sample represented by B, the residue dose;

E = revertants/plate (average, discounting obvious toxic doses) for sample;

F = control revertants/plate (average);

and G = revertants per liter of sample.

SPECIFIC COMPOUND MUTAGENICITY

Several compounds were assayed for mutagenic activity in the Ames test which were previously untested. Some of these compounds were identified in sample fractions as major components by GC/MS (tributyl phosphate and isopropylmyristate). Other compounds (e.g., shikimic acid) were known to be natural carcinogenic products, but their activity in the Ames test was unknown. Although they had not been identified in any sample residues in this study, the fact that they were known natural product carcinogens made them interesting subjcts for study, since there was a finite possibility that residues contained natural product mutagens. A third group of mutagens was assayed as a control check for the derivatization reactions with NTP and $AgNO_3$. None of the compounds were expected to react, and indeed, this was the case. Results of these experiments are shown in Table I-2.

Range of Mutagenic Potencies

Mutagenic substances in the Ames Salmonella microsome mutagen assay are known to encompass a potency range of many orders of magnitude, although the potency of a given mutagen does not necessarily correspond to its potency as an animal carcinogen. Table I-3 shows examples of mutagens (all known carcinogens) encompassing the wide range of specific activities, and shows the concentrations required to cause a level of mutagenicity similar to what has been detected in potable water supplies.

LIST OF ABBREVIATIONS

T	Toxic response
TA98	Strain TA98, no S9
$TA98_9$	Strain TA98 + S9
TA100	Strain TA100, no S9
$TA100_9$	Strain TA100 + S9
R	Repeat assay of total residue; performed with residue fractions
F-#	Fraction number
WP	Very weak positive response
SP	Strongly positive response
N	Negative response (not mutagenic)
NT	Not tested
SJC	San Jose Creek WRP
WN	Whittier Narrows WRP
Pom	Pomona WRP
LA/GL	Los Angeles/Glendale WRP
WF21	Water Factory 21
R.H.S.	Rio Hondo storm flow
L.A.R.	Los Angeles River dry weather runoff
Col R.	Colorado River water
S.P.	State Project water
T.B.	Talbert Barrier observation well
Y.L.	Yorba Linda well
An.	Anaheim well
No. Holly	North Hollywood well
Pollock Coll	Pollock wells collector
2°	Secondary effluent
3°	Tertiary effluent
A.C.	Activated carbon effluent
R.O.	Reverse osmosis effluent
Cl_2	Chlorinated
$UnCl_2$	Unchlorinated
$DeCl_2$	Dechlorinated

TABLE I-1

COMPARISON OF AMES TEST RESULTS FOR TOTAL SAMPLE RESIDUES FROM DIFFERENT LOCATIONS

Sample Location	Sample Number	Date	Revertants/Liter			
			TA98	TA98$_9$	TA100	TA100$_9$
MONTEBELLO FOREBAY						
SJC UnCl$_2$ 2°	1	02/05/79	T	1290	T	N
	19	08/02/79	100	90	T	T
SJC Cl$_2$ 2°	2	02/05/79	N	N	N	N
	20	08/02/79	90	N	N	N
SJC DeCl$_2$ 3°	5	02/22/79	N	N	N	N
	18	07/25/79	870	670	N	2200
	59	06/17/80	4900	1900	5100	3100
WN UnCl$_2$ 2°	3	02/13/79	N	N	N	N
WN Cl$_2$ 2°	4	02/13/79	N	N	N	N
WN DeCl$_2$ 3°	7	03/02/79	N	N	N	N
	28	10/25/79	2760	1730	N	2660
	68	10/06/80	2000	830	3020	1050
Pom DeCl$_2$ 3°	9	03/08/79	N	N	N	N
	31	11/08/79	220	N	710	N
R.H.S.	40	01/28/80	N	2290	1020	N
	80	12/04/80	1270	970	2550	N
	87	01/23/81	2970	3180	1790	N
	88	01/28/81	1430	2090	N	N
	89	02/09/81	2170	2100	N	N
	90	02/26/81	3960	4800	N	N
Col. R.	32	11/15/79	180	N	N	N
	43	02/14/80	130	N	N	N
	86	01/13/81	70	N	N	N
S.P.	33	11/20/79	60	N	N	N
	42	02/07/80	190	50	330	N
	85	01/08/81	160	50	N	N
1580J UnCl$_2$	6	02/26/79	N	N	N	N
	34	11/27/79	300	140	280	N
	49	03/17/80	630	250	N	N

TABLE I-1 (Cont.)

COMPARISON OF AMES TEST RESULTS FOR TOTAL SAMPLE RESIDUES FROM DIFFERENT LOCATIONS

			Revertants/Liter			
Sample Location	Sample Number	Date	TA98	$TA98_9$	TA100	$TA100_9$
MONTEBELLO FOREBAY (Cont.)						
1566A $UnCl_2$	8	03/05/79	N	N	N	N
	35	11/29/79	170	70	200	N
	50	03/31/80	160	40	300	N
2907 Cl_2	10	03/13/79	N	N	N	N
	39	01/23/80	210	70	220	N
	51	04/03/80	160	20	430	N
1591H $UnCl_2$	11	03/15/79	2790	670	N	N
	22	08/22/79	150	60	870	420
	52	04/07/80	200	N	450	N
2958A Cl_2	12	03/21/79	20400	13300	1060	8620
	21	08/20/79	60	N	220	N
	56	04/28/80	180	40	430	140
2947Q $UnCl_2$	15	04/17/79	N	N	N	N
	48	03/13/80	200	100	N	N
	54	04/17/80	N	N	N	N
1514A $UnCl_2$	16	04/19/79	N	N	N	N
	44	02/25/80	170	120	290	N
	55	04/21/80	60	N	N	N
1621MM $UnCl_2$	17	04/24/79	N	N	N	N
	45	03/03/80	1750	200	350	N
	53	04/10/80	2400	1500	2500	N
1620GG $UnCl_2$	23	08/30/79	130	120	590	240
	46	03/06/80	330	270	160	N
	57	05/01/80	280	50	470	200
1562E $UnCl_2$	41	01/31/80	120	110	N	N
	47	03/10/80	110	100	100	N
	58	05/05/80	N	N	240	N
SAN FERNANDO BASIN						
LA/GL Cl_2 3°	14	04/12/79	N	160	N	N
	71	10/23/80	590	360	N	N
	84	12/23/80	850	580	1010	550

TABLE I-1 (Cont.)

COMPARISON OF AMES TEST RESULTS FOR TOTAL SAMPLE RESIDUES FROM DIFFERENT LOCATIONS

Sample Location	Sample Number	Date	Revertants/Liter TA98	 TA98$_9$	 TA100	 TA100$_9$
SAN FERNANDO BASIN (Cont.)						
L.A.R.	37	12/10/79	1230	570	1810	720
	69	10/08/80	1860	840	3000	1150
	83	12/17/80	1400	830	2200	1250
Pollock Coll UnCl$_2$	38	12/13/79	140	90	190	N
	70	10/15/80	230	130	270	N
	81	12/11/80	80	N	230	N
No. Holly UnCl$_2$	36	12/06/79	120	70	150	N
	72	10/29/80	400	250	N	N
	82	12/15/80	120	110	250	N
ORANGE COUNTY - TALBERT GAP AND ANAHEIM FOREBAY						
WF21 A.C. Cl$_2$	13	04/04/79	N	40	N	N
	65	09/22/80	400	130	1080	430
WF21 R.O. Cl$_2$	64	09/18/80	130	50	330	N
WF21 R.O. UnCl$_2$	77	11/17/80	110	50	310	N
T.B. M-10 UnCl$_2$	30	11/05/79	130	60	N	N
	66	09/25/80	290	70	510	200
	78	11/25/80	70	N	220	N
T.B. M-12 UnCl$_2$	29	10/29/79	230	80	112	N
	67	09/30/80	500	190	610	270
	79	12/02/80	60	N	250	N
Y.L.#11 Cl$_2$	24	09/24/79	N	400	220	N
	60	09/02/80	680	140	760	250
	73	11/04/80	270	200	N	N
An. #22 UnCl$_2$	26	10/15/79	N	N	N	N
	63	09/15/80	170	80	200	N
	76	11/12/80	110	80	140	N
An. #27 UnCl$_2$	25	10/04/79	180	N	290	N
	61	09/08/80	360	120	550	N
	74	11/06/80	310	240	N	N
An. #29 UnCl$_2$	27	10/22/79	72	50	N	N
	62	09/11/80	110	90	160	N
	75	11/10/80	130	100	250	N

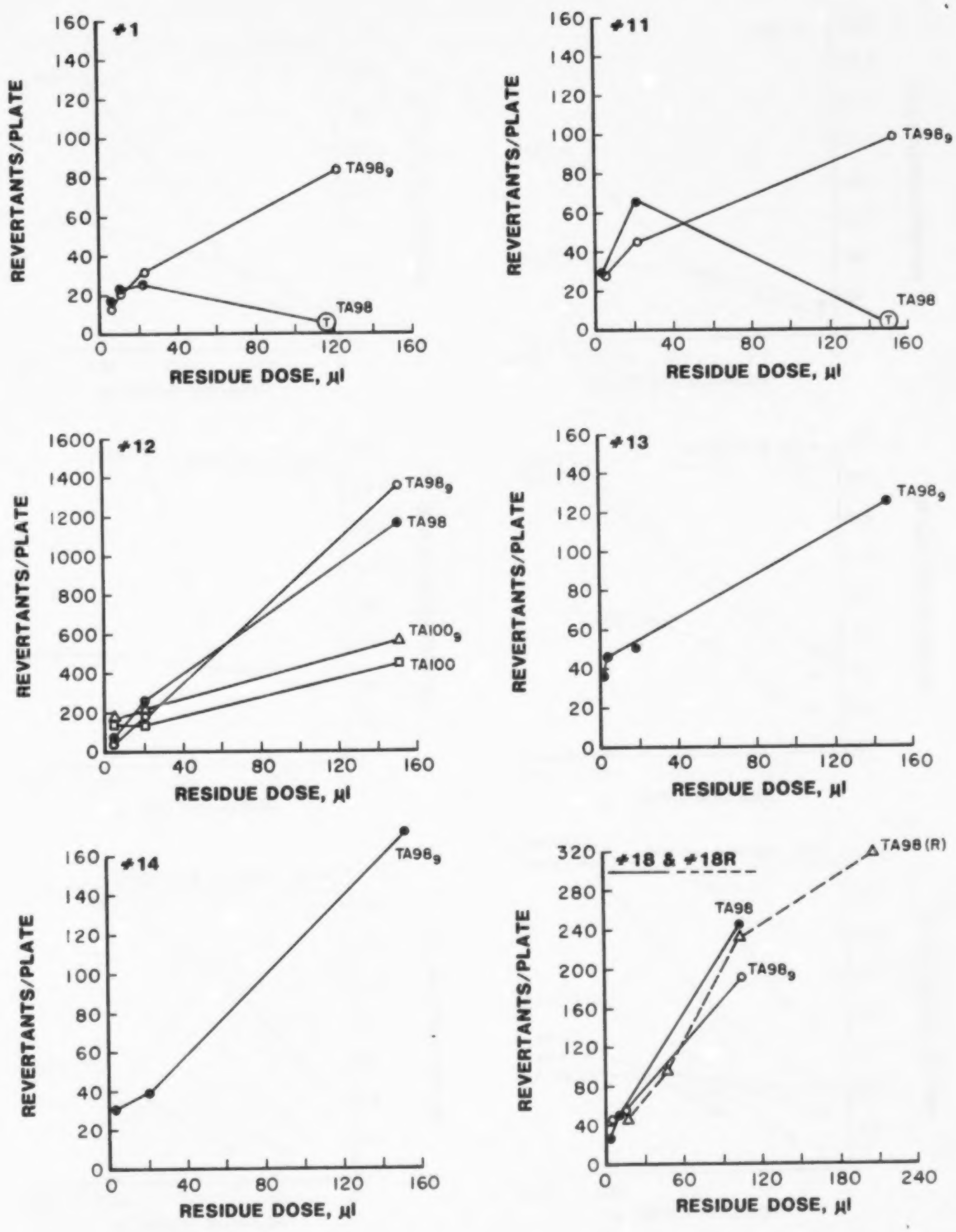
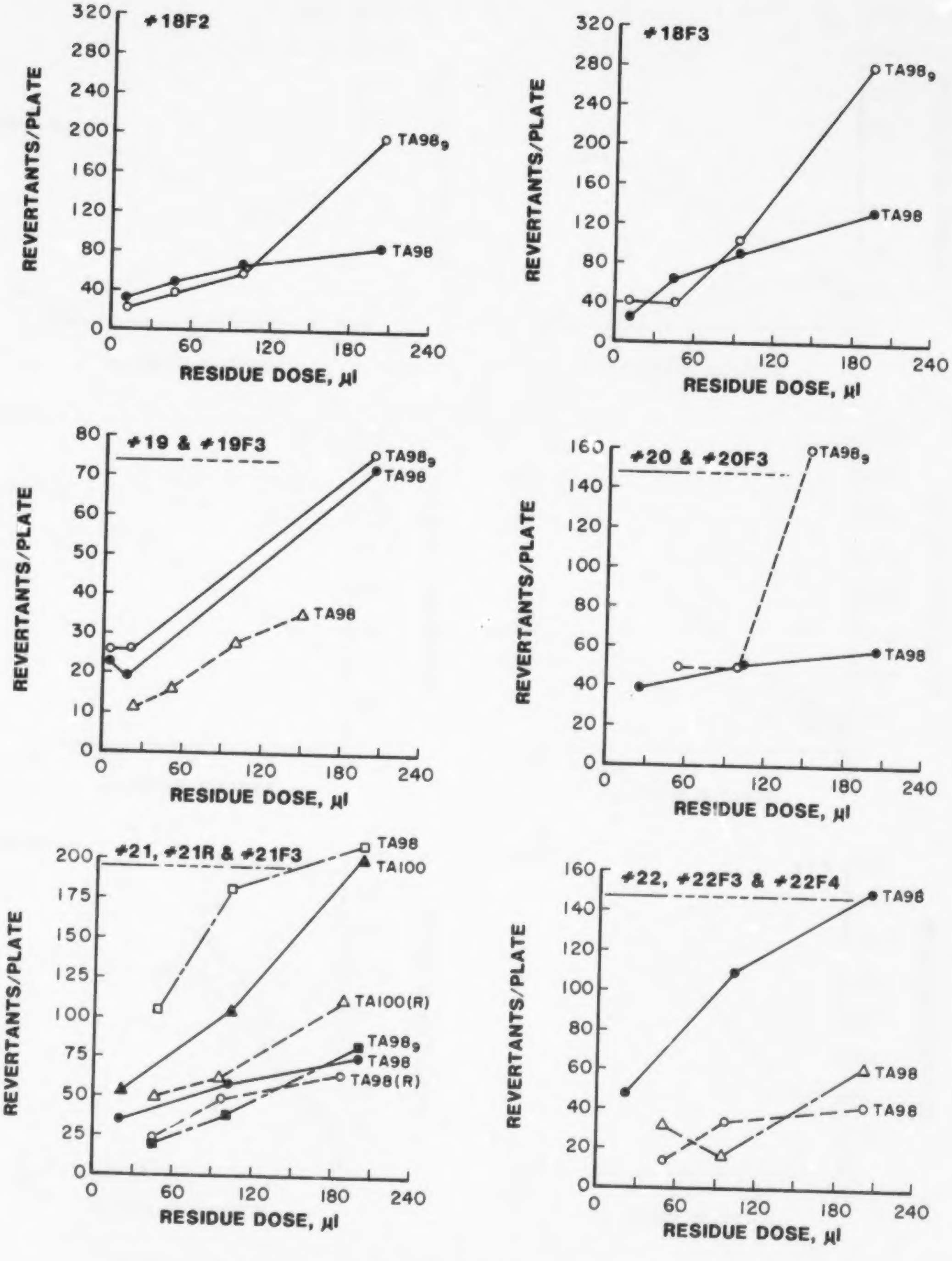


FIGURE I-1 RESULTS OF AMES ASSAYS FOR RESIDUES AND FRACTIONS



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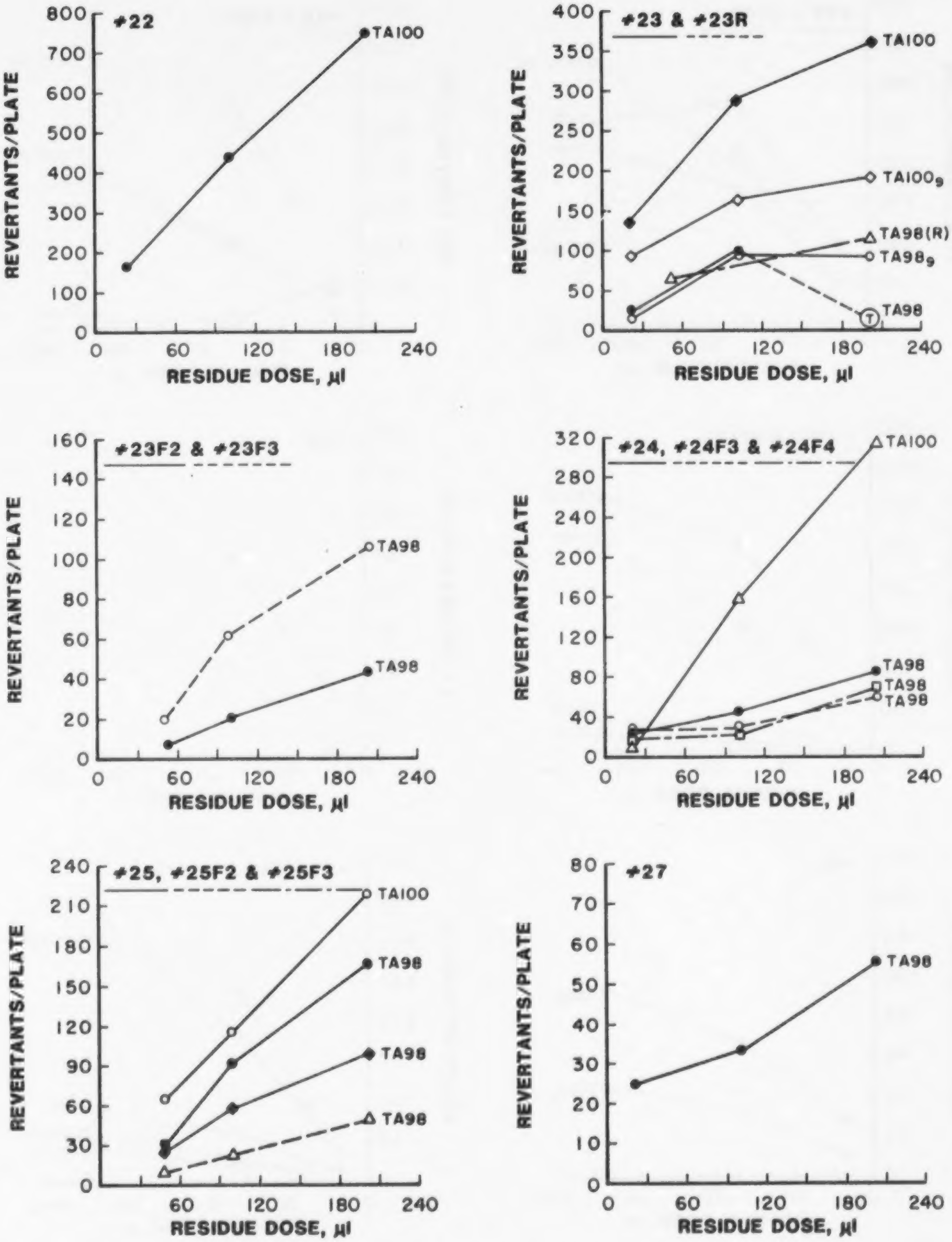

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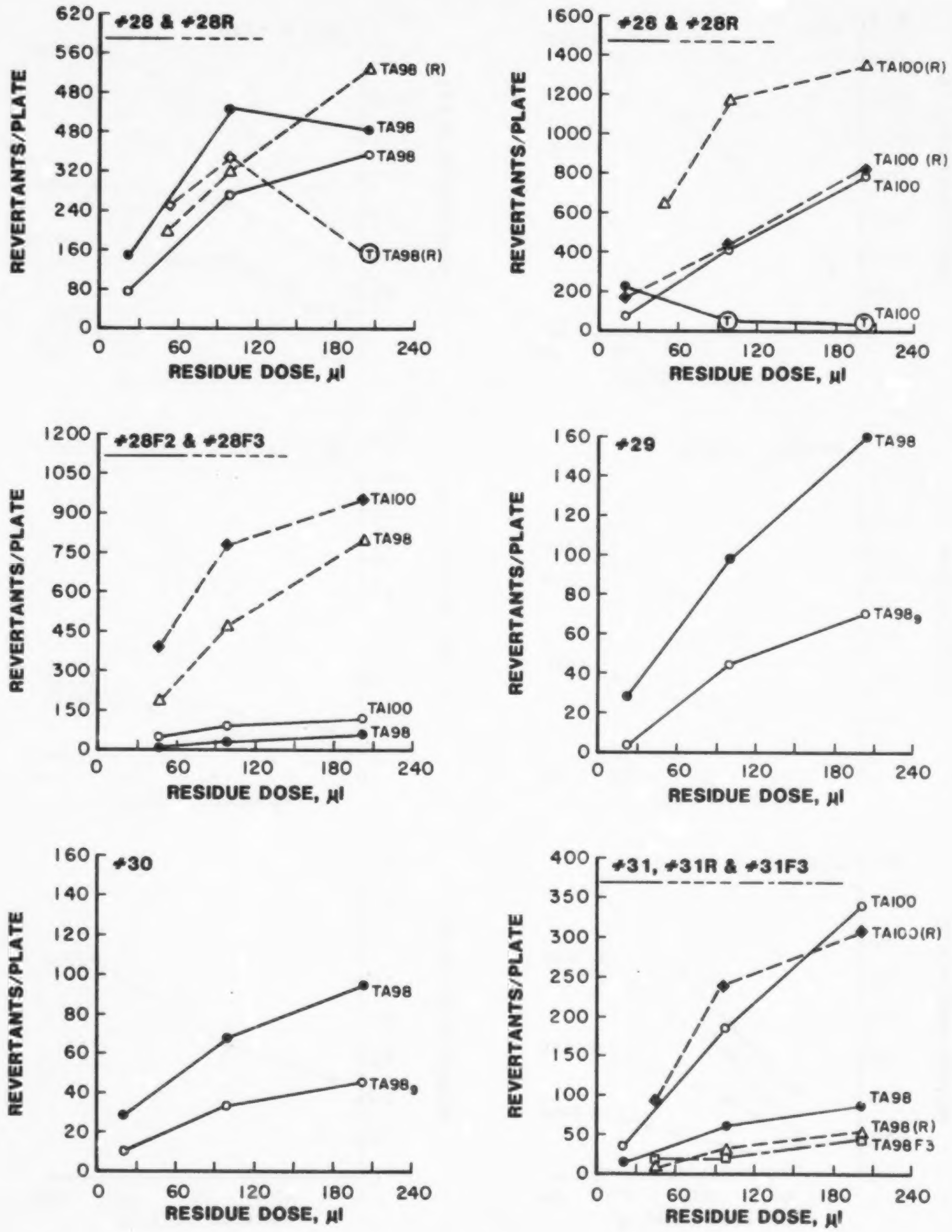

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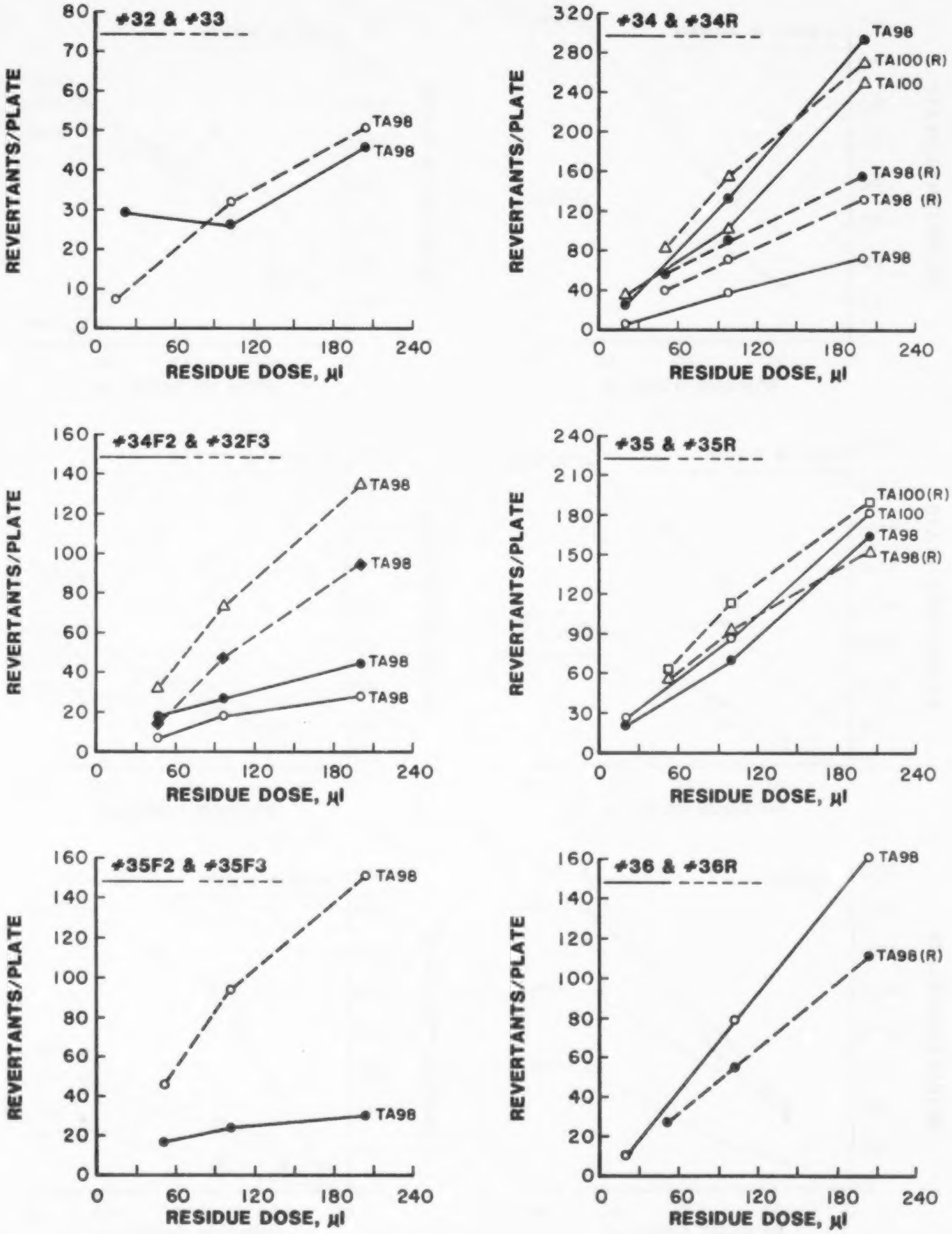

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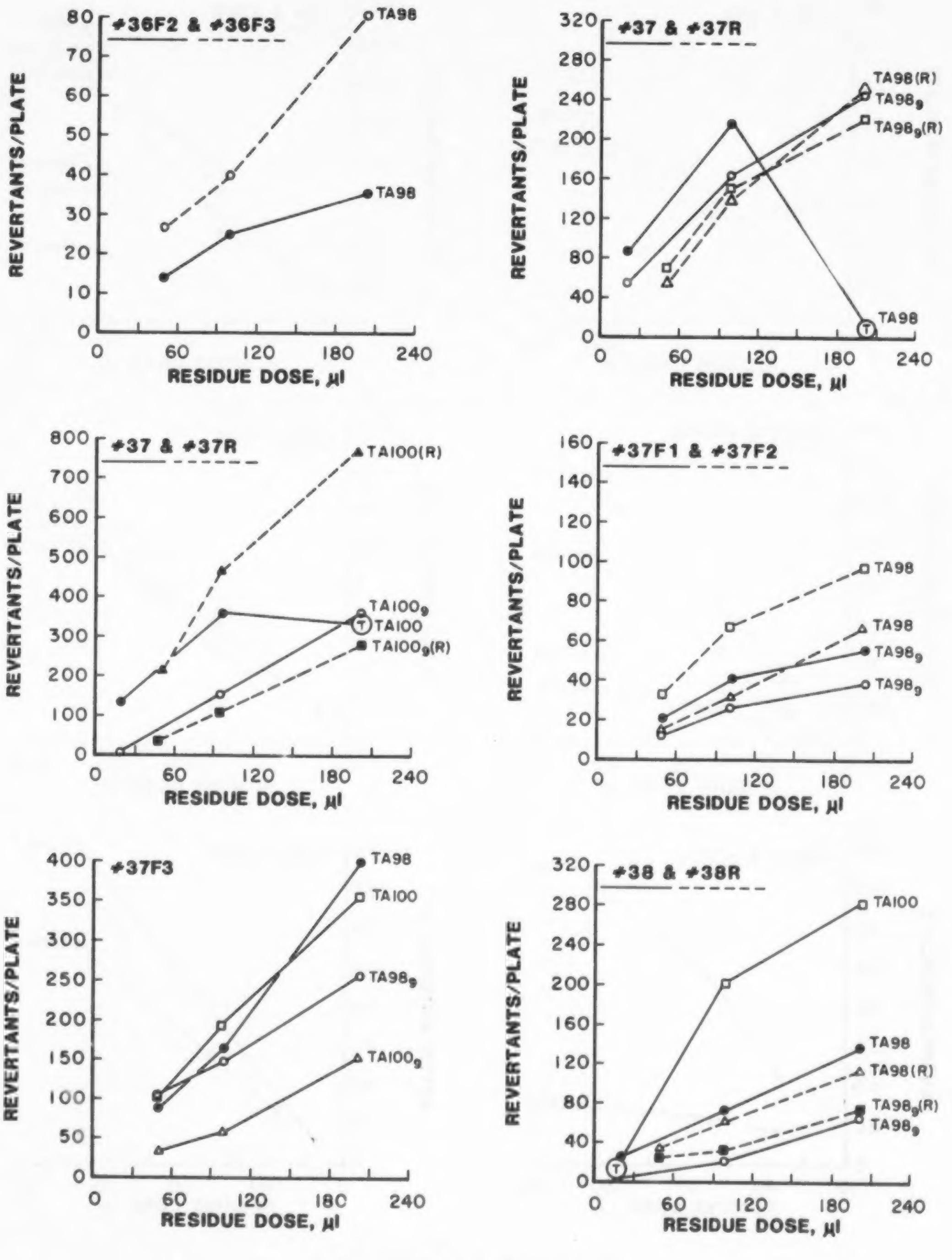

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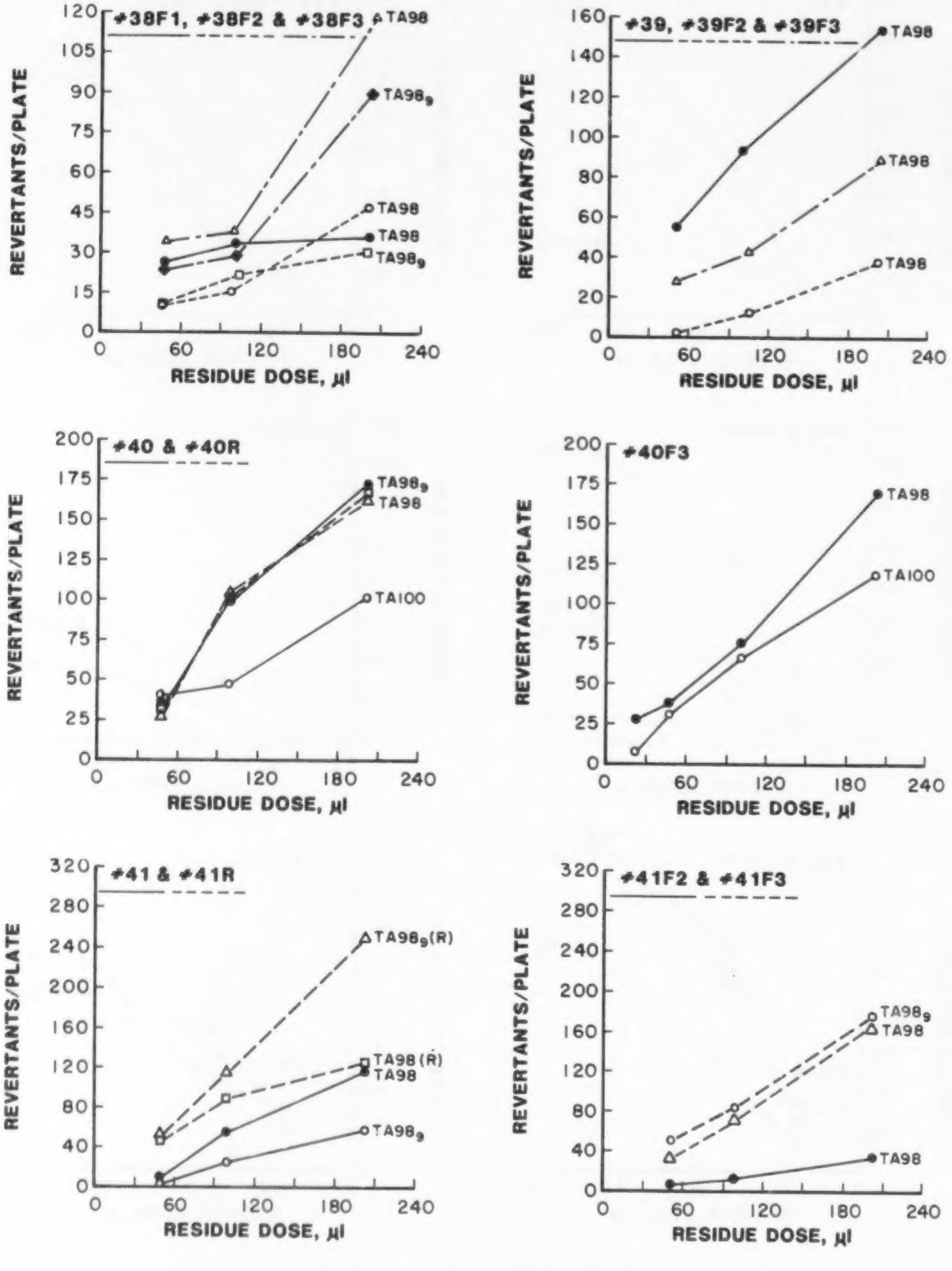

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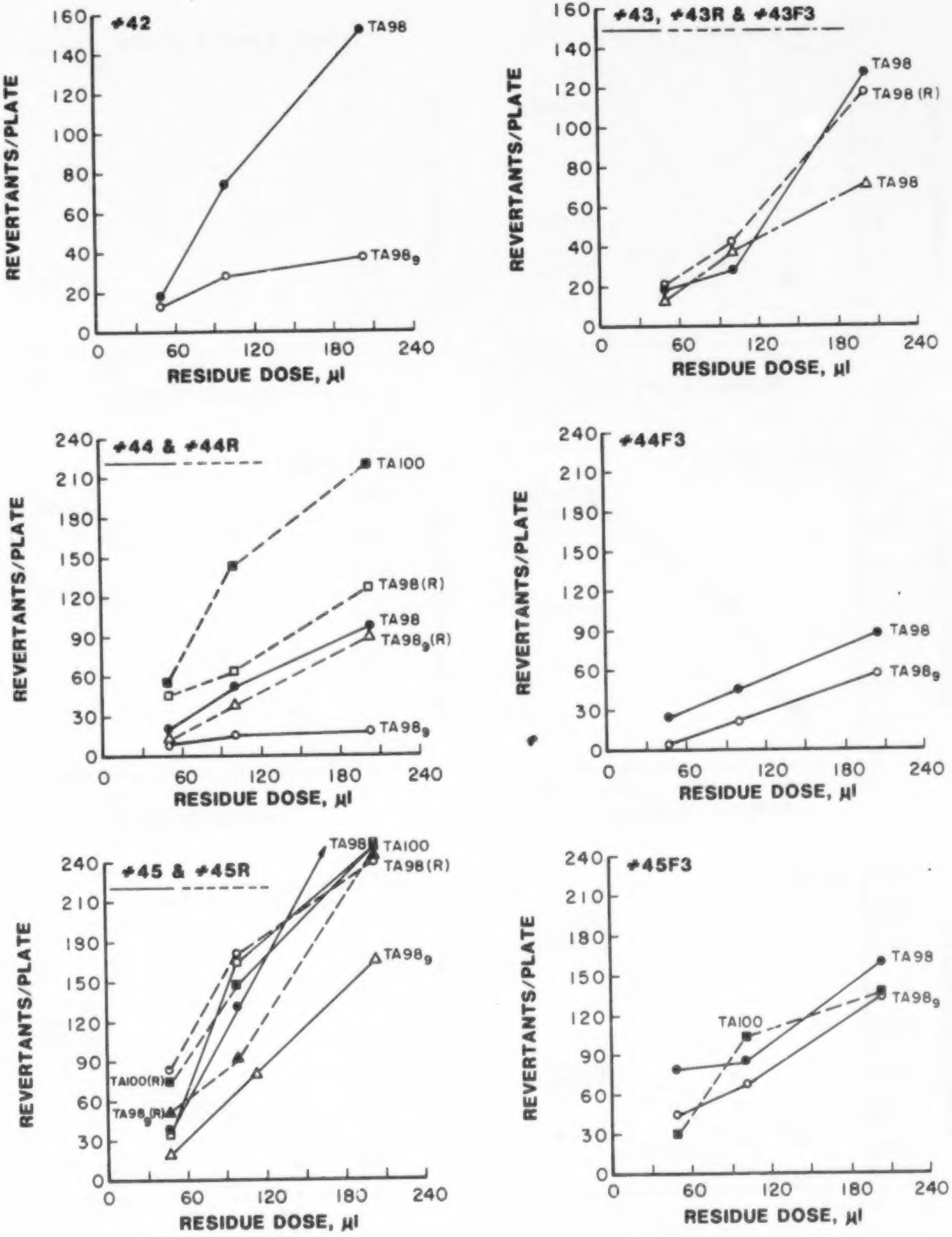

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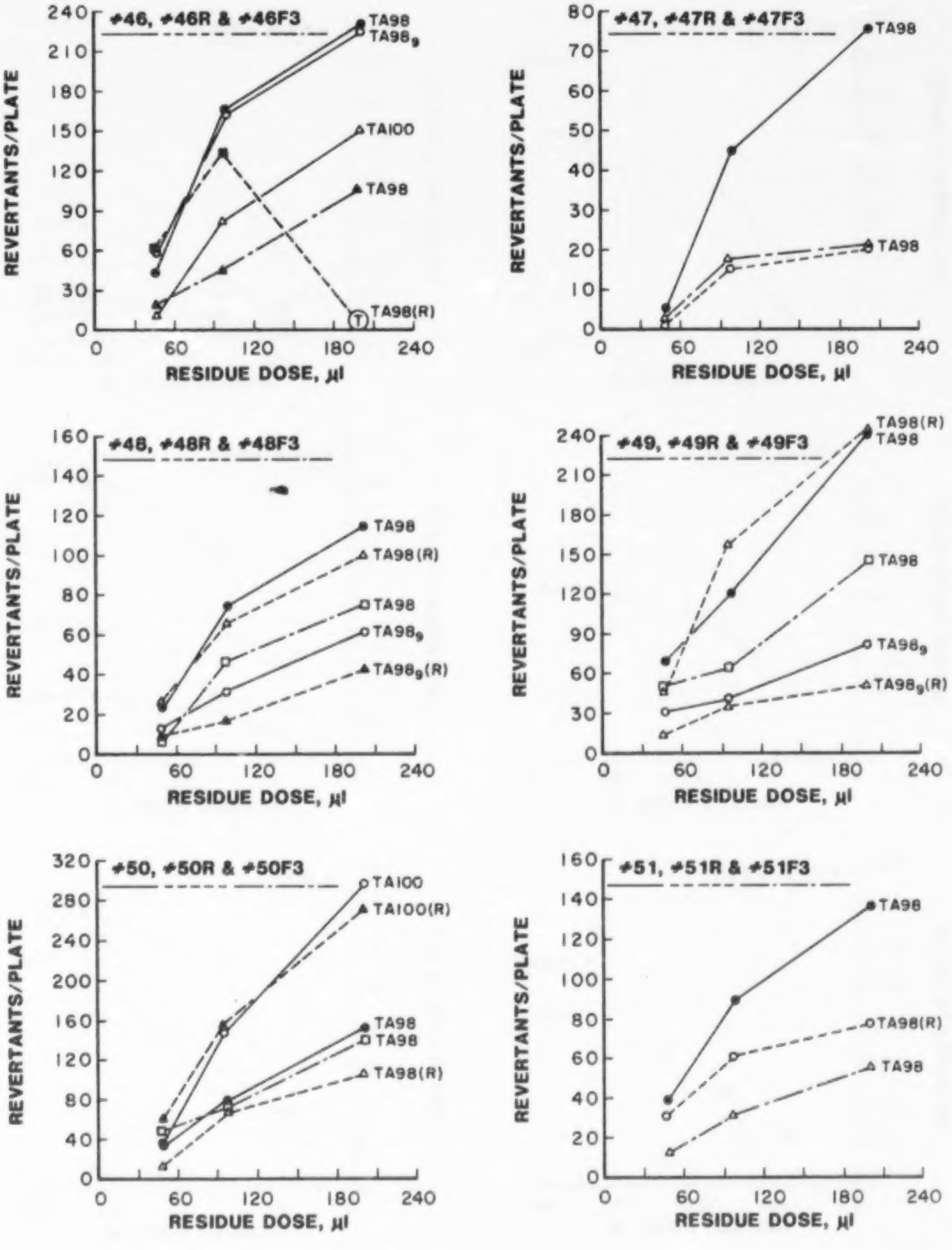

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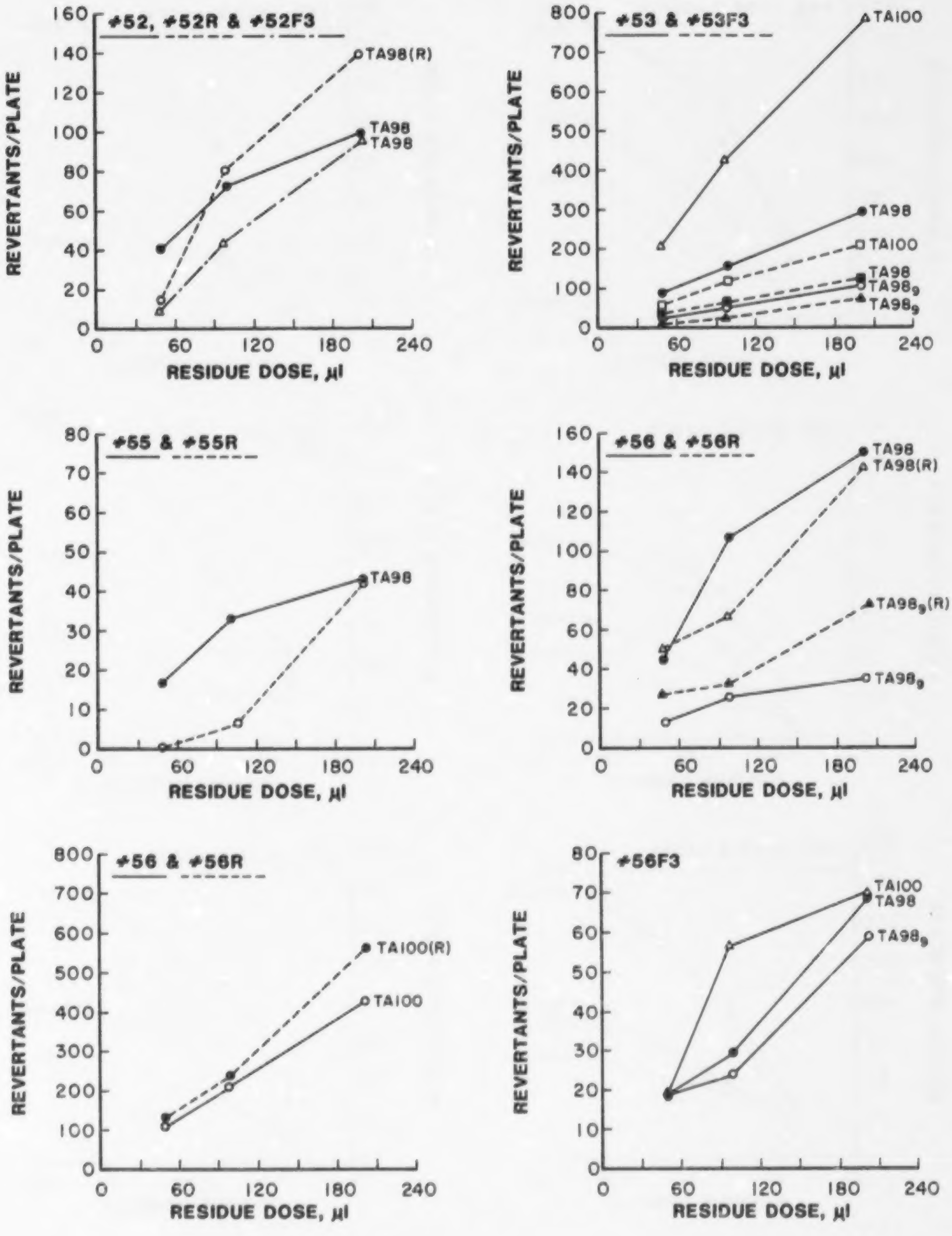

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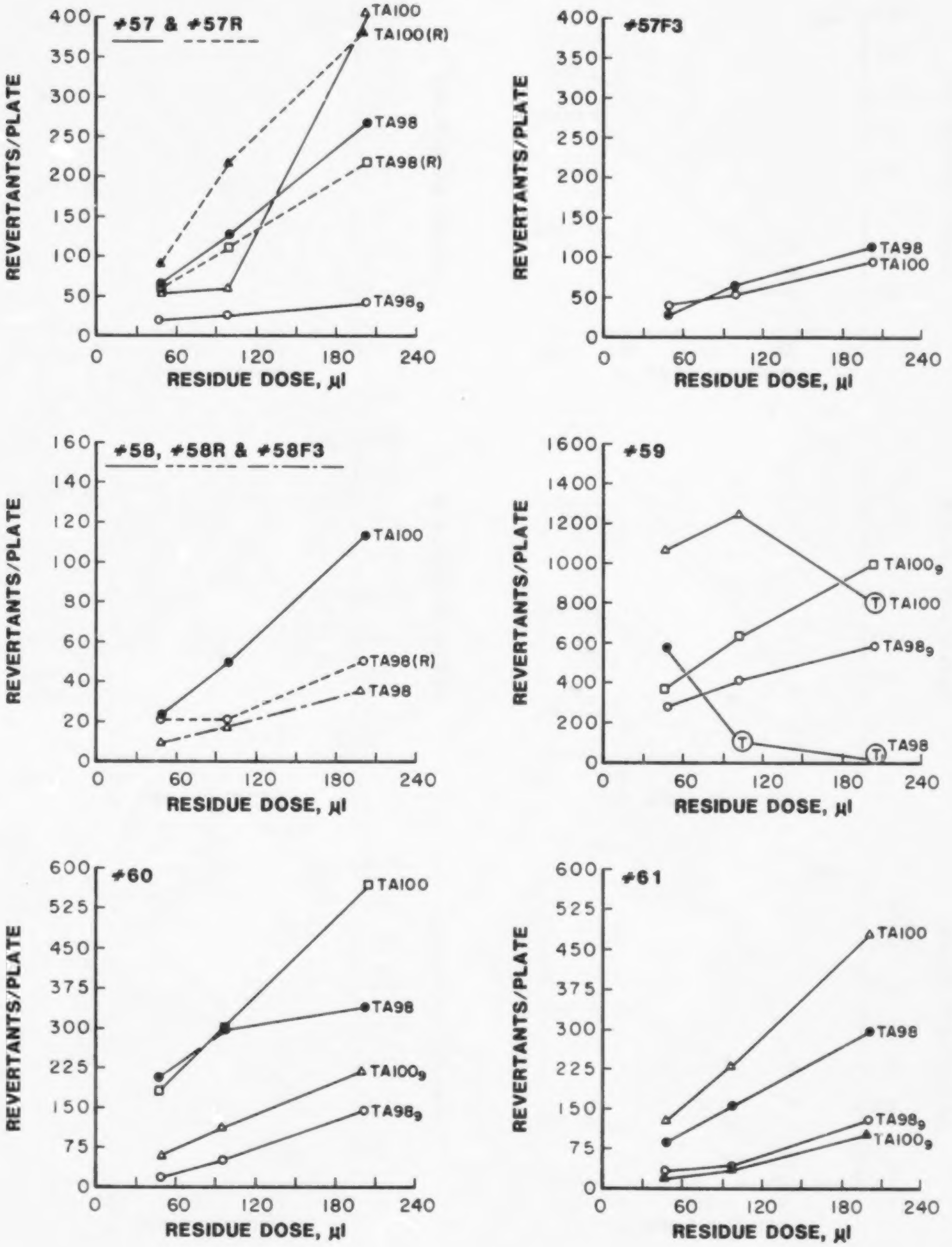

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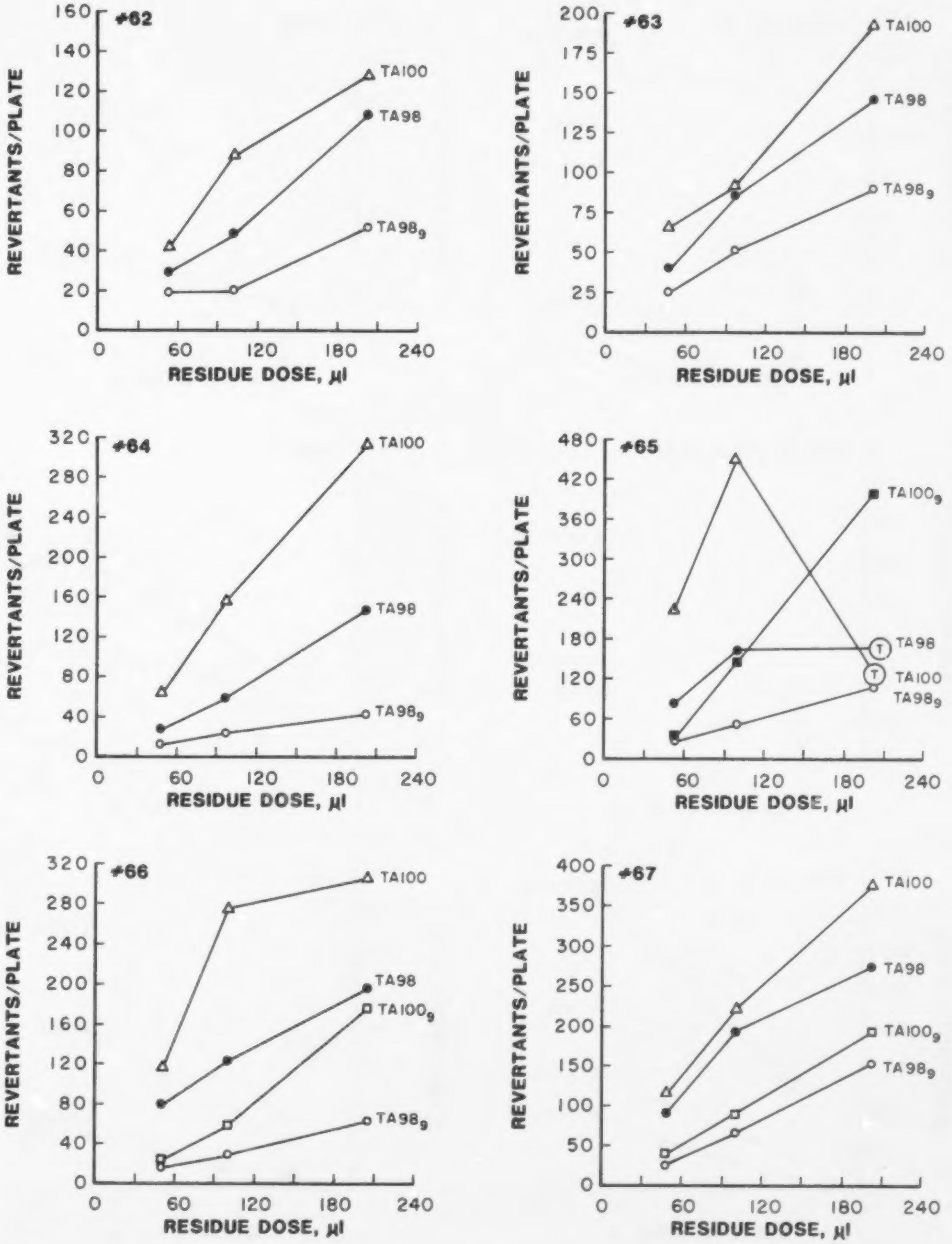

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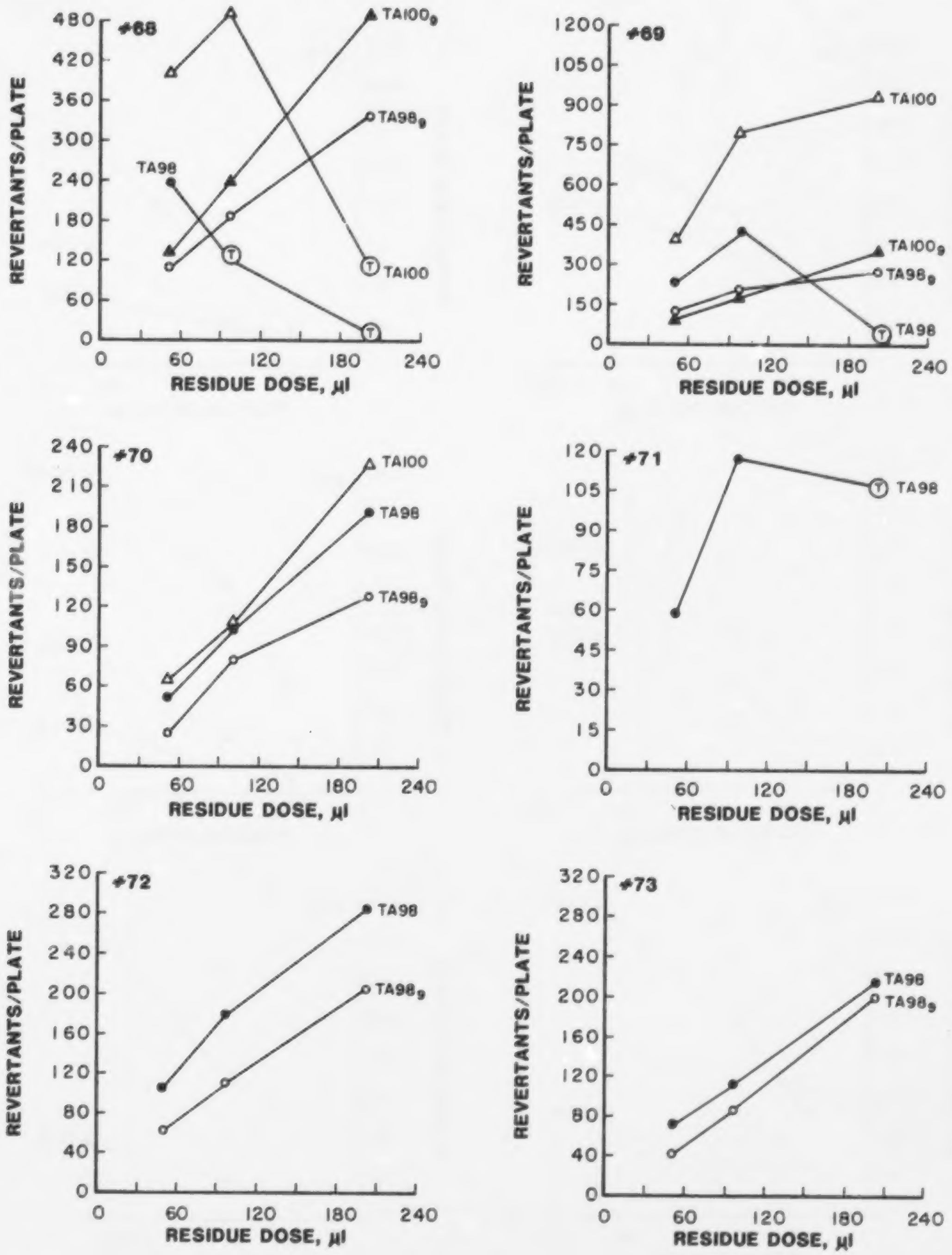

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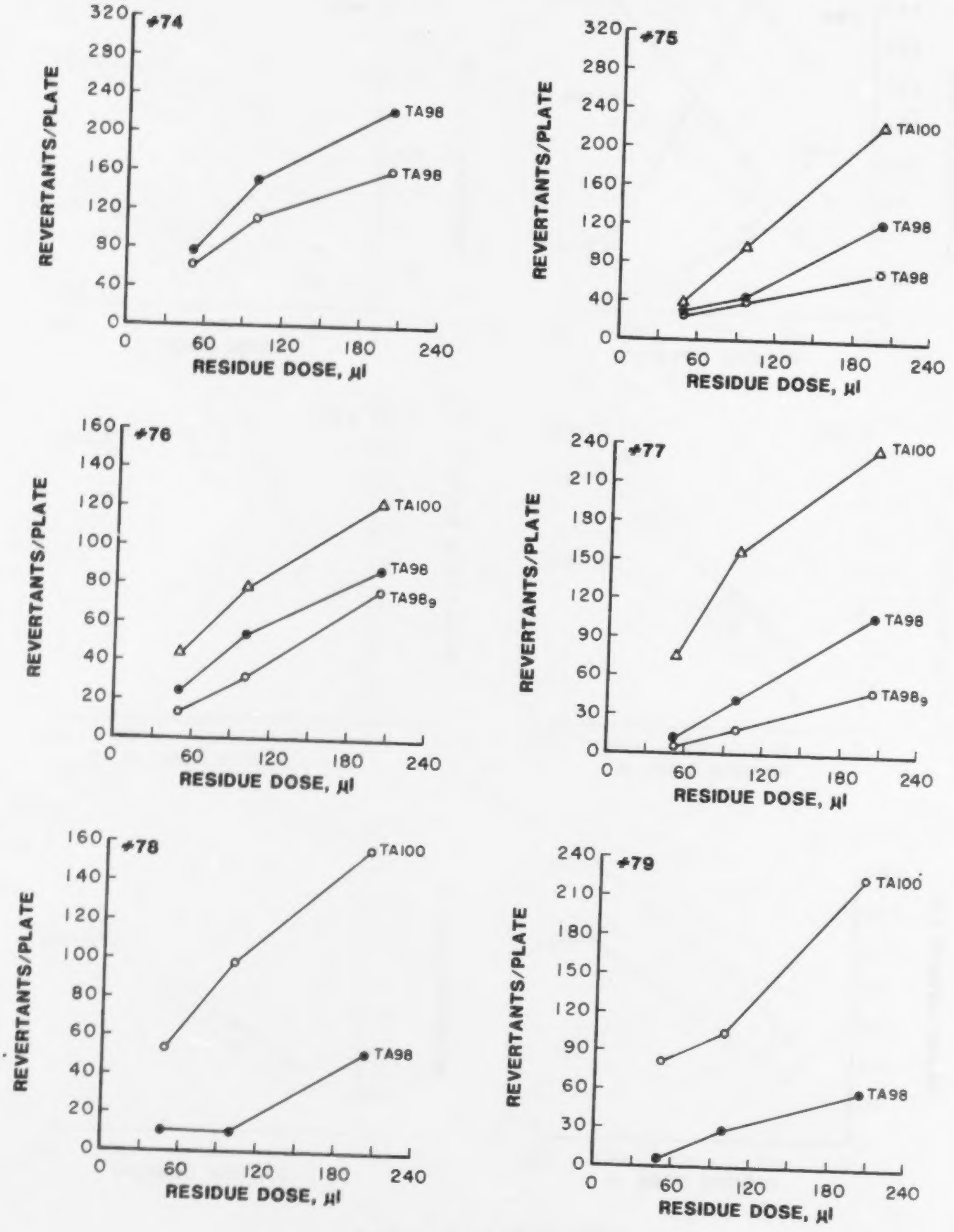

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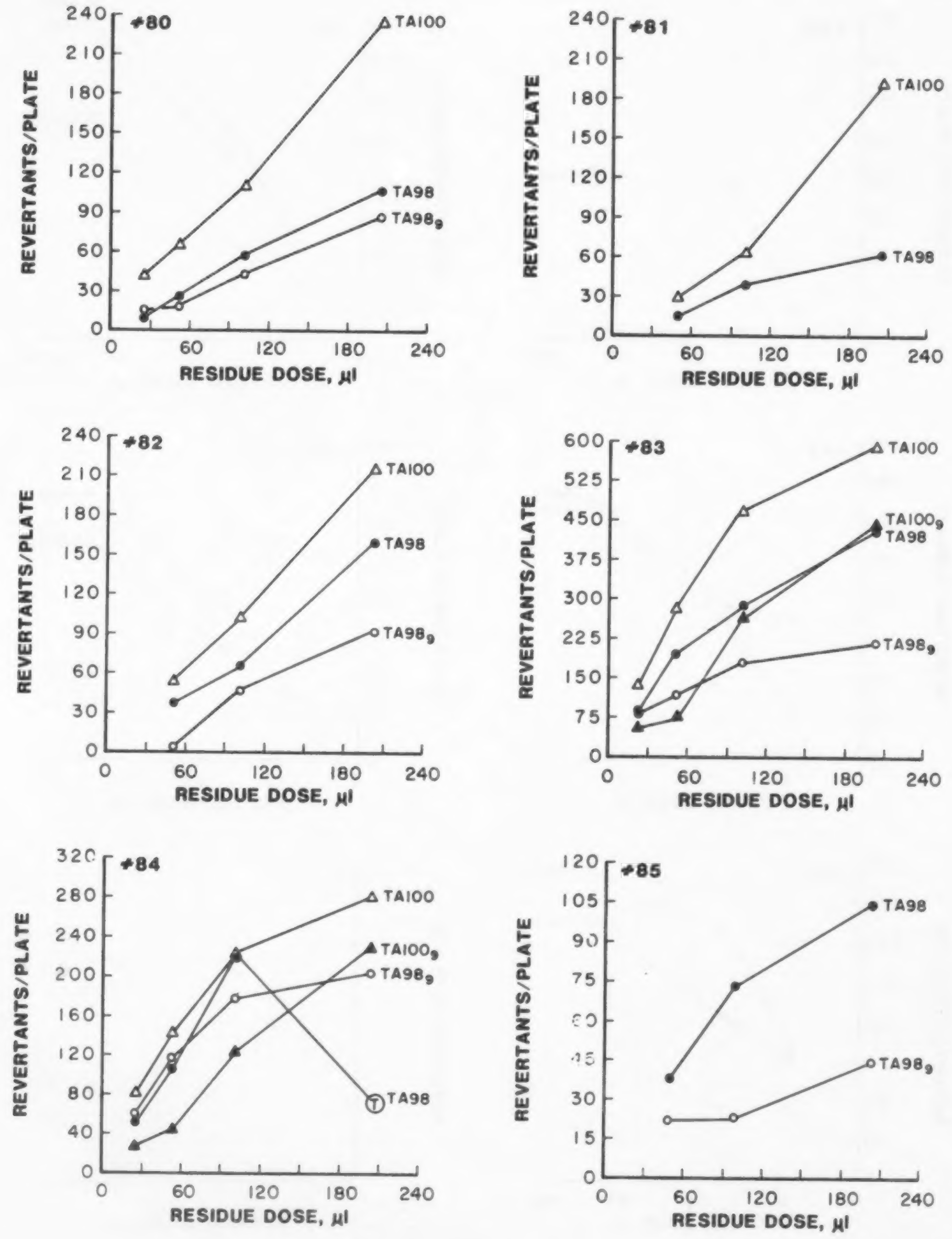

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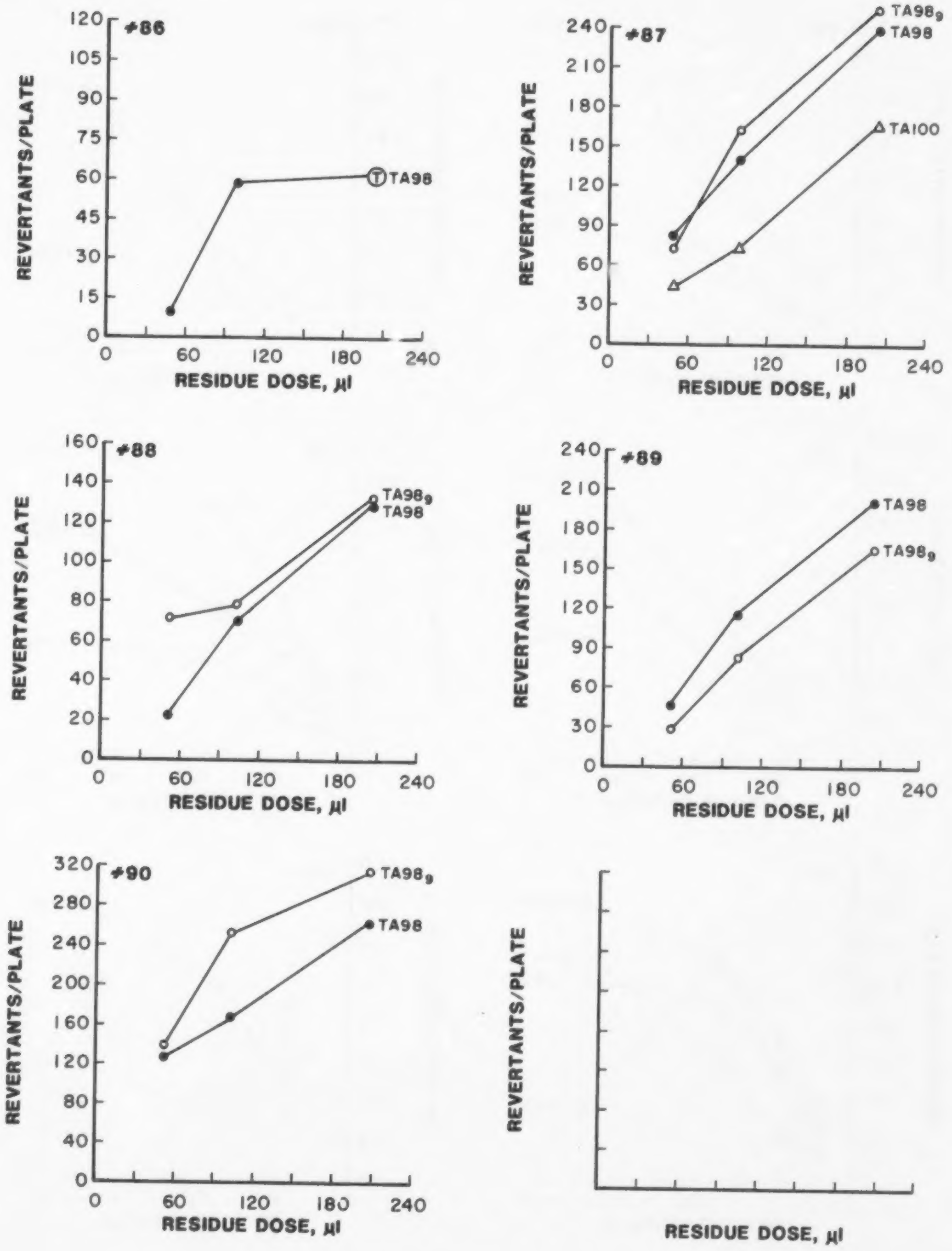

FIGURE I-1 cont.

TABLE I-2

AMES ASSAY RESULTS FOR SPECIFIC ORGANICS TESTED DURING HEALTH EFFECTS STUDY[a], [b]

Compound	Maximum Dose (μg)	Maximum Reversion Rate (sample:control)							
		TA98	TA98g	TA100	TA100g	TA100FRI	TA1535	TA1535g	Notes
4-nitrothiophenol(NTP)	38	1.98	NT	3.39	NT	0.83	1.00	NT	WP
5-nitrofurantoin(5-NF)	50	6.3	NT	10.4	NT	8.5	NT	NT	SP
5-NF+NTP	50	T	NT	10.5	NT	8.5	NT	NT	SP
4-nitroquinoline-1-oxide(4-NQO)	1	11.2	NT	10.4	NT	9.4	NT	NT	SP
4-NQO+NTP	1	11.5	NT	10.5	NT	9.8	NT	NT	SP
9-aminoacridine(9-AA)	75	NT	NT	NT	NT	NT	6.6	NT	SP
9-AA+NTP	75	NT	NT	NT	NT	NT	6.8	NT	SP
2,7-diaminofluorene(DAF)	200	8	NT	NT	NT	NT	NT	NT	SP
DAF+NTP	200	5.5(+)	NT	NT	NT	NT	NT	NT	SP
Daunorubicine(DAUNO)	10	3.1	NT	1.3(+)	NT	NT	NT	NT	SP
DAUNO+NTP	10	3.9	NT	2.0	NT	1.2	NT	NT	SP
Tributyl phosphate	500	1.0	0.8	0.8	0.8	NT	0.9	0.8	N
Isopropylmyristate	500	1.1	0.8	0.9	0.9	NT	1.1	0.8	N
Diphenamide	500	0.7	1.1	1.1	0.9	NT	0.8	1.2	N
Shikimic Acid	500	1.3	0.8	0.8	1.3	NT	NT	NT	N
Coumarin	500	1.1	1.1	0.8	0.8	NT	NT	NT	N

[a] Plate incorporation, dose response, MRR calculated after subtraction of controls form sample response.
[b] Equimolar NTP added to known mutagens (non-epoxide, non-alkylhalide direct acting mutagens).

TABLE I-3

RANGE OF SPECIFIC ACTIVITIES OF MUTAGENS AND CORRELATION WITH SAMPLE MUTAGENICITY AND THEORETICAL RISK ESTIMATES

Compound	Revertants/ng a/		Concentration (μg/L) Producing 150 Rev/L in Ames Test		EPA Water Quality Criteria 10^{-5} Risk Factor b/ (ng/L)
	TA98	TA100	TA98	TA100	
Aflatoxin	1.9	2.3	0.08	0.07	1.0
Benzo(a)pyrene	137x10^{-3}	480x10^{-3}	1090	312	9.7
Benzidine	64x10^{-3}	c/	2340	c/	1.67
Toxaphene	3.25x10^{-4}	5.0x10^{-5}	46x10^{4}	30x10^{5}	0.5
2,6-dinitrotoluene	d/	3.0x10^{-5}	d/	50x10^{5}	740
N-nitrosopyrrolidine	1.75x10^{-4}	c/	148x10^{4}	c/	0.11
chlordane	d/	2.75x10^{-6}	d/	54x10^{6}	1.2

a/ See Ref. IV-60.
b/ See Ref. IV-58.
c/ Negative response.
d/ Positive response, but no specific activity given in the literature.

APPENDIX J

LISTING OF CARCINOGENS AND MUTAGENS IN THE NBS MASS SPECTRAL LIBRARY AND THOSE NOT FOUND IN THE NBS LIBRARY

INTRODUCTION

Table J-1 lists compounds whose mass spectra are in the computerized 25,000 NBS library and which are known to be mutagens in the Ames test or have been reported to be animal carcinogens in valid bioassays. This table, then, represents a list of health significant materials to which GC/MS data for mutagenic fractions were compared for the purpose of trying to identify the cause(s) of sample mutagenicity.

Table J-2 lists known Ames test mutagens which are not in the NBS library. For these compounds, parent ions from EI spectra of unknowns in mutagenic fractions were manually checked against molecular weights. Although this was not a rigorous proof that the compounds in Table J-2 were not present, this check was the only means of taking a first cut at these materials.

TABLE J-1

CARCINOGENS AND MUTAGENS IN THE NBS LIBRARY

Compound	Molecular Weight
Ethyleneimine	43
Propyleneimine	57
Methyloxirane (Propylene oxide)	58
Trimethylene oxide (Oxetane)	58
Acetamide	59
1,2-dimethyl hydrazine	60
Ethenyloxirane (1,2-epoxy-3-butene)	70
Ethyloxirane (1,2-epoxybutane)	72
N-methyl-N-nitrosomethaneamine	74
Oxiranemethanol (2,3-Epoxy-1-propanol)	74
Thiourea	76
2,2'-bioxirane (1,2,3,4-diepoxybutane)	86
2-chlorobutadiene (2-chloro-2-butene)	89
1-chloro-2-propanone	92
Benzeneamine	93
Chloroacetic acid	94
2-methylthiophene	98
1-nitroso-pyrrolidine	100
N-ethyl-N-nitrosoethaneamine	102
N-methyl-N-nitrosourea (N-nitrosomethylurea)	103
Styrene (Ethenylbenzene)	104
Sorbic acid (2,4-hexadienoic acid)	112
N-nitrosopiperidine	114
Bis-(chloromethyl)ether	114
N-nitrosomorpholine	116
N-ethyl-N-nitrosourea (N-nitrosoethyl urea)	117
Trimethylthiourea	118
Styrene oxide (Ethenyloxybenzene)	120
1,3-diamino-4-methylbenzene (2,4-diaminotoluene)	122
Benzylchloride (Chloromethylbenzene)	127
Naphthalene	128
3-methyl-1H-indene	130
N-nitroso-N-propyl propanamine	130
N-nitroso-N-methyl urethane (Carbamic acid, Methylnitroso-,Ethylester)	132
N,N'-diethylthiourea	132
3-phenyl-2-propenal (Cinnemaldehyde)	132
3-pyridinecarboxylic acid hydrazine	137
1-ureidopyridinum hydroxide (Isoniazid)	137
2-naphthalenamine (-naphthylamine)	143
1-naphthol (1-naphthalenol)	144
2H-1-benzopyran-2-one	146
L-methionine	149
Carbon tetrachloride	152
3-bromopropanoic acid	152
2-bromopropionic acid	153

TABLE J-1 Cont.

CARCINOGENS AND MUTAGENS IN THE NBS LIBRARY

Compound	Molecular Weight
N-butyl-N-nitroso-1-butanamine	158
Fluorene (9H-Fluorene)	166
1,2,3-Trimethoxybenzene	168
2-aminobiphenyl	169
4-aminobiphenyl	169
Anthracene	178
Phenanthrene	178
Acridine	179
2-aminofluorene (9H-Fluoren-2-amine)	181
Azobenzene	182
Benzidine	184
1-naph tylisothiocyanate	185
Ethylenedibromide	186
N-nitroso-N-pentyl-1-pentanamine	186
4-nitroquinoline-1-oxide	190
4-amino-*trans*-stilbene	195
N-nitroso-N-phenylbenzenamine	198
4-nitro-1,1'-biphenyl	199
Simazine	201
Pyrene	202
5,7-dimethoxy-2H-1-benzopyran-2-one	206
Anthraquinone	208
4-aminomethylazobenezene	211
4-aminoazobenzene	212
Atrazine	215
2-acetylaminofluorene (N-9H-fluoren-2-yl-acetamide)	223
N,N-dimethyl-4-aminoazobenzene	225
N-nitroso-N-(phenyl-benzenemethanamine)	226
Benz(a)anthracene	228
Chrysene	228
7-methylbenz(a)anthracene	242
4,4'-sulfonyl-bis-benzeneamine (DAPSO)	248
Benzo(a)pyrene	252
Benzo(e)pyrene	252
N,N-diethyl-4-aminoazobenzene	252
5,5'-diphenyl-2,4-imidazolidinedione	252
7,12-dimethylbenz(a)anthracene	256
7,10-dimethylbenz(e)acridine	257
Dibenz(a,h)anthracene	278
Aflatoxin	312

TABLE J-2

CARCINOGENS AND MUTAGENS NOT IN NBS LIBRARY

Compound	Molecular Formula	Molecular Weight
Sodium azide	N_aN_3	65
Hydroxylamine hydrochloride	$NH_2OH \cdot HCl$	69
-propiolactone	$C_3H_4O_2$	72
2,3-epoxypropionaldehyde	$C_3H_4O_2$	72
Ethylcarbamate	$C_3H_7O_2N$	89
Thioacetamide	C_2H_5NS	75
N-(2-hydroxyethyl)hydrazine	$C_2H_8ON_2$	76
-butyrolactone	$C_4H_6O_2$	86
Methylazoxymethanol	$C_7H_4O_2N$	90
Chloroethylmethylether	C_3H_7OCl	94
Maleic anhydride	$C_4H_2O_3$	98
Dimethylcarbamyl chloride	C_3H_6NOCl	107
Methylmethanesulfonate	$C_2H_6O_3S$	110
Maleic hydrazide	$C_4H_4O_2N_2$	112
-caprolactone	$C_6H_{10}O_2$	114
1,3-propanesultone	$C_3H_6SO_3$	122
Ethylmethanesulfonate	$C_3H_8SO_3$	124
Dimethylmaleic anhydride	$C_6H_6O_3$	126
Diazoacetylglycine amide	$C_4H_7N_3O_2$	129
Hydrazine sulfate	$(NH_2)_2 \cdot H_2SO_4$	130
Methylazoxymethanol acetate ester	$C_4H_8N_2O_3$	132
p-quinonedioxime	$C_6H_4(NOH)_2$	138
1,2-dimethyl-5-nitroimidazole	$C_5H_7O_2N_3$	141
Hexyl oxirane (1,2,7,8-diepoxyoctane)	$C_8H_{14}O_2$	142
Bis-(2-chloroethyl)amine	$C_5H_2Cl_2N_2$	142
5-nitro-2-furamidoxime	$C_4H_4N_3O_3$	142
Diazoacetylglycine hydrazide	$C_4H_8N_4O_2$	144
N-methyl-N-nitro-N-Nitroso-guanidine	$C_2H_5N_5O_3$	147
Carbon Tetrachloride	CCl_4	152
Diethylsulfate	$(C_2H_5)_2SO_4$	154
Di-(2-chloroethyl)methylamine	$C_5H_{11}NCL_2$	155
Methyl-bis-(2-chloroethyl)amine	$C_5H_{11}NCl_2$	155
5-nitro-2-furoic acid	$C_5H_3O_5N$	157
2-nitrosonaphthalene	$C_{10}H_7NO$	157
Di(2-chloroethyl)sulfide	$(C_2H_4Cl)_2S$	158
Diazoacetylglycine, ethyl ester	$C_6H_{10}O_3N_2$	158
N-hydroxy-1-amino naphthalene	$C_{10}H_9ON$	159
N-hydroxy-2-amino naphthalene	$C_{10}H_9ON$	159
N'-nitroso-N-nitro-N-propylguanidine	$C_5H_{12}N_4O_2$	160
N-ethyl-N'-nitro-N-nitrosoguanidine	$C_3H_7N_5O_3$	161
Safrole	$C_{10}H_{10}O_2$	162
1-(2-hydroxyethyl)-2-methyl-5-nitroimidazole (metronidazole)	$C_6H_9O_3N_3$	171
2-nitronaphthalene	$C_{10}H_7NO_2$	173

TABLE J-2 Cont.

CARCINOGENS AND MUTAGENS NOT IN NBS LIBRARY

Compound	Molecular Formula	Molecular Weight
Azaserine (Serine diazoacetate)	$C_5H_7O_4N_3$	173
N-propyl-N'-nitro-N-nitrosoguanidine	$C_4H_9N_5O_3$	175
4-hydroxyaminoquinoline-1-oxide	$C_9H_8O_2N_2$	176
1-hydroxysafrole	$C_{10}H_{10}O_3$	178
N-butyl-N'nitro-N-nitroso-guanidine	$C_5H_{11}N_5O_3$	189
N-isobutyl-N'-nitro-N-nitroso-guanidine	$C_5H_{11}N_5O_3$	189
thio-TEPA	$C_6H_{12}N_3PS$	189
1-aminoanthracene	$C_{14}H_{11}N$	193
2-aminoanthracene	$C_{14}H_{11}N$	193
9-aminoacridine	$C_{13}H_{10}N_2$	194
2-nitrosofluorene	$C_{13}H_9NO$	195
2,7-diaminofluorene	$C_{13}H_{12}N_2$	196
N-hydroxy-2-aminofluorene	$C_{13}H_{11}NO$	197
2,3-dimethyl-4-aminobiphenyl	$C_{14}H_{14}N$	197
5-nitroacenapthene	$C_{12}H_9NO_2$	199
Ethyl-p-toluene sulfonate	$C_9H_{12}SO_3$	200
N-pentyl-N'-nitro-N-nitroso-guanidine	$C_6H_{13}N_5O_3$	203
tris-(2-chloroethyl)amine	$C_6H_{12}Cl_3N$	203
2-nitrofluorene	$C_{13}H_9NO_2$	211
N-hydroxy-4-aminoazobenzene	$C_{12}H_{11}N_3O$	213
1-(5-nitro-2-thiazoly)-2-imidazolidinone (niridazole)	$C_6H_6N_4O_3S$	214
3-chloro-4-dichloromethyl-5-hydroxy-2(5H)-furanone	$C_5H_3O_3Cl_3$	216
1-aminopyrene	$C_{16}H_{11}N$	217
N-hexyl-N'-nitro-N-nitrosoguanidine	$C_7H_{15}N_5O_3$	217
N,N-di-(2-chloroethyl)aniline	$C_{10}H_{13}NCl_2$	217
1-acetoxysafrole	$C_{12}H_{12}O_4$	220
4-acetyl-2-aminofluorene	$C_{15}H_{13}NO$	223
2-aminoanthraquinone	$C_{14}H_9O_2N$	223
4-dimethylamino-*trans*-stilbene	$C_{16}H_{12}N$	223
o-aminoazotoluene	$C_{14}H_{15}N_3$	225
1,8,9-trihydroxyanthracene	$C_{14}H_{10}O_3$	226
4-aminomethoxyazobenzene	$C_{13}H_{13}N_3O$	227
N-(5-nitrofurfurylidene)-1-aminohydantoin	$C_8H_6N_4O_5$	238
4-aminotrimethylazobenzene	$C_{15}H_{17}N_3$	239
N-hydroxy-2-acetyl-2-aminofluorene	$C_{15}H_{13}O_2N$	239
1-hydroxy-2-acetyl-2-aminofluorene	$C_{15}H_{13}O_2N$	239
3-hydroxy-2-acetyl-2-aminofluorene	$C_{15}H_{13}O_2N$	239
5-hydroxy-2-acetyl-2-aminofluorene	$C_{15}H_{13}O_2N$	239
7-hydroxy-2-acetyl-2-aminofluorene,	$C_{15}H_{13}O_2N$	239
2-methyl-4-dimethylaminoazobenzene	$C_{15}H_{17}N_3$	239
N-[4-(5-nitro-2-furyl)thiazolyl]-formamide	$C_8H_5O_4N_3S$	239

TABLE J-2 Cont.

CARCINOGENS AND MUTAGENS NOT IN NBS LIBRARY

Compound	Molecular Formula	Molecular Weight
10-chloromethyl-9-methyl anthracene	$C_{16}H_{13}Cl$	240
benz(a)anthracene-5,6-oxide	$C_{18}H_{10}O$	242
Chrysene-5,6-oxide	$C_{18}H_{10}O$	242
6-aminochrysene	$C_{18}H_{13}N$	243
2-(2-furyl)-3-(5-nitro-2-furyl)-acrylamide	$C_{11}H_8O_5N_2$	248
p-dimethylaminobenzenediazo sodium-sulfonate	$C_8H_{10}N_3SO_3Na$	251
2-methyl-1-nitroso anthraquinone	$C_{15}H_9NO_3$	251
Uracil Mustard	$C_8H_{11}Cl_2N_3O_2$	252
7,8-dihydrobenzo(a)pyrene	$C_{20}H_{14}$	254
7,9-dimethylbenz(c)acridine	$C_{19}H_{15}N$	257
10-chloromethyl-9-chloroanthracene	$C_{15}H_{10}Cl_2$	260
Cyclophosphamide	$C_7H_{15}Cl_2N_2O_2P$	261
2,7-diacetylaminofluorene	$C_{17}H_{14}NO_2$	264
Acridine Orange(base)	$C_{17}H_{19}N_3$	265
Benzo(a)pyrene-4,5-oxide	$C_{20}H_{10}O$	266
Chlornaphazine	$C_{14}H_{15}Cl_2N$	268
Diethylstilbesterol	$C_{18}H_{20}O_2$	268
3-hydroxybenzo(a)pyrene	$C_{20}H_{12}O$	268
3-methylcholanthrene	$C_{21}H_{16}$	268
10-bromomethylanthracene	$C_{15}H_{11}Br$	270
7-hydroxymethyl-12-methylbenz(a)-anthracene	$C_{20}H_{16}O$	272
9,10-dichloromethylanthracene	$C_{16}H_{12}Cl_2$	274
1,2-dihydro-2-(5-nitro-2-thienyl) quinazolin-4-(3H)-one	$C_{12}H_9N_3O_3S$	275
7-chloromethylbenz(a)anthracene	$C_{19}H_{13}Cl$	276
Dibenz(a,c)anthracene	$C_{22}H_{14}$	278
Dibenz(a,j)acridine	$C_{21}H_{12}N$	279
6-hydroxymethyl benzo(a)pyrene	$C_{21}H_{14}O$	282
Proflavine (dihydrochloride)	$C_{13}H_{13}Cl_2N_3$	282
Dibenz(a,h)anthracene-5,6-oxide	$C_{22}H_{12}O$	290
7-chloromethyl-12-methylbenz(a) anthracene	$C_{20}H_{15}Cl$	290
N-acetoxy-2-acetylaminofluorene	$C_{18}H_{16}NO_3$	294
Folpet	$C_9H_4Cl_3NO_2S$	295
Captan	$C_9H_8Cl_3NO_2S$	299
Dibenzo(a,c)pyrene	$C_{24}H_{14}$	302
Dibenzo(a,i)pyrene	$C_{24}H_{14}$	302
Aflatoxicol	$C_{17}H_{14}O_6$	314
Aflatoxin B_2	$C_{17}H_{14}O_6$	314
4-bis-(2-hydroxyethylamino)-2-(5-nitro-2-thienyl) quinazoline	$C_{14}H_{12}O_3N_4S$	316

TABLE J-2 Cont.

CARCINOGENS AND MUTAGENS NOT IN NBS LIBRARY

Compound	Molecular Formula	Molecular Weight
Sterigmatocystin	$C_{18}H_{11}O_6$	324
Methyl orange	$C_{14}H_{14}N_3SO_3Na$	327
Aflatoxin M_1	$C_{17}H_{12}O_7$	328
N-benzoyloxy-4-Methylaminoazobenzene	$C_{20}H_{17}N_3O_2$	331
1,1-Diphenyl-2-propynyl-N-cyclohexylcarbamate	$C_{22}H_{22}NO_2$	333
7-Bromomethyl-12-methylbenz(a) anthracene	$C_{20}H_{15}Br$	334
Gibbirellic acid	$C_{19}H_{22}O_6$	346
1,1-Diphenyl-2-butynyl-N-cyclohexylcarbamate	$C_{23}H_{23}NO_2$	347
1-Phenyl-1-(3,4-xylyl)-2-propynyl-N-cyclohexylcarbamate	$C_{24}H_{27}NO_2$	361
Penicillin G	$C_{16}H_{17}O_4N_2S$	372
Octachloro-di-n-propylether	$C_6H_6Cl_8O$	374
Ethidium bromide	$C_{21}H_{20}BrN_3$	393
Tetracycline	$C_{22}H_{24}N_2O_8$	444
Daunorubicin HCl	$C_{27}H_{30}ClNO_{10}$	563
Adriamycin HCl	$C_{27}H_{29}NO_{11}\cdot HCl$	579
4-bis-(2-hydroxyethylamino)-2-(5-nitro-2-thienyl)-quinazoline	$C_{28}H_{22}O_6N_6S_2$	602

APPENDIX K

MASS SPECTRAL DATA FOR PESTICIDES AND METABOLITES

INTRODUCTION

This appendix contains the results of a library search for available mass spectral data of pesticides known to have been used in the Montebello Forebay area or those which seem to be related in types of applications and popularity. Included where available are data for known metabolites of the parent compounds. The tables are arranged such that metabolites are listed after each respective parent compound. References and major mass spectral peaks are presented. This appendix represents another literature data base (in addition to Appendices J and L) to which unknown mass spectra were compared for possible identification.

APPENDIX K

MASS SPECTRA OF PESTICIDES AND METABOLITES

COMPOUNDS/METABOLITES	MW	EI BASE m/z	OTHER EI m/z	CI BASE m/z	OTHER CI m/z	REFERENCE
N,N-dimethyldiphenylacetamide	239	167	239,238			K-1
N,N-dimethyl-2-phenyl-2-(hydroxyphenyl-p-O-D-glucosyl)-acetamide	585	169	585,184,183,109,72,331			K-2
N-methyl-2-phenyl-2-(hydroxyphenyl--O-D-glucosyl)-acetamide	571	169	331,184,183,109,58			K-2
N,N-demethyl-2-phenyl-2-hydroxyphenylacetamide	255	72	255,184,183,165,105			K-2
N-methyl-2-phenyl-2-hydroxyphenylacetamide	241	183	241,184,58			K-2
2-phenyl-2-hydroxyphenylacetamide	227	183	227,184,72,57			K-2
N-methyl-2,2-diphenylacetamide	225	167	225,168,166,165,58			K-2
2-2-diphenylacetamide	211	167	211,168,166,165,43			K-2
2,2-diphenylacetic acid	212	167	212,168,166,165,152,57			K-2

APPENDIX K (Cont.)

MASS SPECTRA OF PESTICIDES AND METABOLITES

COMPOUNDS/METABOLITES	MW	EI BASE m/z	OTHER EI m/z	CI BASE m/z	OTHER CI m/z	REFERENCE
N-methyl-N-hydroxymethyl-2,2-diphenylacetamide-β-D-glucoside	585	169	418,331, 168,167, 166,165, 109			K-2
N-methyl-N-hydroxymethyl-2,2-diphenylacetamide-β-D-gentiobioside	873	169	619,331, 168,167, 166,109,			K-2
N-methyl-N-hydroxymethyl-2,2-diphenylacetamide-β-D-glucoside	585	169	418,331 168,167 166,165 109			K-2
N-methyl-N-hydroxymethyl-2,2-diphenylacetamide-β-D-gentiobioside	873	169	619,331, 168,167, 166,109			K-2
Malathion	330	127	173,158, 125,93			K-3
	330			127	173,128, 125,93 (methane)	K-4
	330	173	79,93,99, 125,126, 127,128, 143,145, 157,158, 159,160, 173,174, 211,256, 284,295, 330			K-5

APPENDIX K (Cont.)

MASS SPECTRA OF PESTICIDES AND METABOLITES

COMPOUNDS/METABOLITES	MW	EI BASE m/z	OTHER EI m/z	CI BASE m/z	OTHER CI m/z	REFERENCE
Malathion (Cont.)	330			331	173,175, 285,127, 159 (isobutane)	K-8
Malaoxon	314	127	93,109, 125,195, 142,99, 314			K-3
	314			127	173,143, 128 (methane)	K-4
Parathion	291	97	291,93, 109,121, 125,263, 235,186, 155,139			K-3
Parathion	291			292	326,320, 294,293 (methane)	K-4
Parathion	291	109	63,65,93, 97,123, 125,137, 139,153, 181,235, 291			K-5
Chlorpyriphos	349	197	349,316, 314,260, 258,199, 125,109, 97,93			K-3,6,7

APPENDIX K (Cont.)

MASS SPECTRA OF PESTICIDES AND METABOLITES

COMPOUNDS/METABOLITES	MW	EI BASE m/z	OTHER EI m/z	CI BASE m/z	OTHER CI m/z	REFERENCE
Metabolite of Chlorpyriphos	361	97	361,328, 326,300, 298,272, 270,211, 209,125			K-7
Chlorthiophos	360	269	362,360, 327,325, 299,297, 271,207, 125,97			K-7
Bromophos	364	331	364,333	367 (isobutane)	369,365	K-3,8
			329,125, 109,97, 93	(methane)	287,111	
Bromophos-ethyl	392	303	371,359,	395 (isobutane)	397,393	K-3,6,8
			331,329, 301,242, 241,240, 125,121, 109,93, 65		303,139, 111	
Fenthion	278	278	169,125, 121,109, 93	279		K-3,8
Fenitrothion	277	125	277,260, 125,121, 109,93,			K-3

APPENDIX K (Cont.)

MASS SPECTRA OF PESTICIDES AND METABOLITES

COMPOUNDS/METABOLITES	MW	EI BASE m/z	OTHER EI m/z	CI BASE m/z	OTHER CI m/z	REFERENCE
Fenchlorphos	320	285	289,287, 125,109, 97,93	321	325,323, 145,127, 111 (isobutane)	K-3,8
Phosmet	317	160	317,161, 125,93	160 (methane)	318,161	K-3,4
					171	
Phosmet Oxon	301			160 (methane)	161	K-4
				319 (NH_3)	302,160	K-4
Dimethoate	229	87	229,125, 93	199 (methane)	258,230	K-3,4,8
				230 (isobutane)		
Dimethoxon	213			214	201,198, 116,88, 87 215,196, 183,182, 156	K-4
Carbophenothion	342	157	342,172, 159,144, 125,121, 109,93, 93	157 (methane)	343,199	K-3,4,8
				343 (isobutane)	159,153	
Carbophenoxon	326			157	327,185, 183,159,	K-4
Carbophenothion Sulfoxide	358			199 (methane)	359,201, 200,153, 75	K-4

APPENDIX K (Cont.)

MASS SPECTRA OF PESTICIDES AND METABOLITES

COMPOUNDS/METABOLITES	MW	EI BASE m/z	OTHER EI m/z	CI BASE m/z	OTHER CI m/z	REFERENCE
Carbophenoxon Sulfoxide	342			183	345,343, 185,139, 109,75, 61	K-4
Carbophenothion Sulfone	374			199 (methane)	377,375, 329,201, 175,161, 153,125, 97,89,87, 89,87,61	K-4
Carbophenoxon Sulfone	358			359 (methane)	361,360, 183,177, 175,159, 157,149, 108,87	K-4
Phorate	260	75	260,231, 125,121, 97,93	75 (methane) 261 (isobutane)	261,199, 153	K-3,4,8
Phorate Oxon	244			75 (methane)	245,183	K-4
Phorate Sulfoxide	276			199 (methane)	277,201, 200,171, 107	K-4
Phorate Oxon Sulfoxide	260			183 (methane)	261,215, 155,153, 127,109, 107,87, 81	K-4

APPENDIX K (Cont.)

MASS SPECTRA OF PESTICIDES AND METABOLITES

COMPOUNDS/METABOLITES	MW	EI BASE m/z	OTHER EI m/z	CI BASE m/z	OTHER CI m/z	REFERENCE
Phorate Sulfone	292			171 (methane)	293,247, 199,193, 155,153	K-4
Phorate Oxon Sulfone	276			183 (methane)	249,185, 157,155, 127,109, 87,81	K-4
Methyl Parathion	263	109	263,125	264 (methane) (isobutane)	292,266, 265,125, 111,109	K-3,4,8
Ethyl Parathion	291			292 (methane) (isobutane)		K-8
Ronnel						
[O,O-dimethyl-O-(2,4,5-trichlorophenyl)phosphorothionate]	320	285	125,109, 93,79	323 (methane)	325,234, 322,321, 287,285, 160,127, 125	K-4,5
Diazinon	304	137	304,276, 248,199, 179,152, 125,121, 109,97, 93	305 (methane) (isobutane)	333,306, 305,259, 179,153, 152,137, 135,97, 93	K3,4,5,8
Diazinon-O-analog	288	137	288,273, 260,93			K-3

APPENDIX K (Cont.)

MASS SPECTRA OF PESTICIDES AND METABOLITES

COMPOUNDS/METABOLITES	MW	EI BASE m/z	OTHER EI m/z	CI BASE m/z	OTHER CI m/z	REFERENCE
Dichlorvos	220	109	220,187, 185,145, 97,93	220 (methane) 221 (isobutane)	225,223, 222,187, 185,141, 127,109, 60	K-3,4,8
Naled	378	109	220,187, 185,145, 97,93	127	383,379, 303,301, 299,157, 155,147, 145,126, 109	K-3,4
Mevinphos	224	127	224,192, 164,109	193 (methane)	226,225, 194,192, 127	K-3,4
				193 (methane D4)	226,225, 194,192, 128,127, 100	K-4
Phosphamidon	299	127	264,193, 138,109, 93	100 (methane) 300 (isobutane)	302,300, 228,226, 194,192, 176,174, 141,140, 127,119, 111,101, 72	K-3,4,8

MASS SPECTRA OF PESTICIDES AND METABOLITES

COMPOUNDS/METABOLITES	MW	EI BASE m/z	OTHER EI m/z	CI BASE m/z	OTHER CI m/z	REFERENCE
Phosphamidon (Cont.)				100 (methane)	303,301, 227,193, 176,174, 128,127, 101,99, 72	K-4
Azinphosmethyl	317			335 (NH_3)	318,166, 160,78	K-4
	317	160	317,132, 125,105, 104,93	160 (methane) (isobutane)	161,159, 132,127, 125,113	K-3,4,8
Azinphosmethyl-O-analog	301	160	301,132, 109,104			K-3
Azinphosethyl	345	132	186,160, 125,121, 109,105, 104.97, 93	160 (isobutane)	346,187, 134,132	K-3,8
EPN	323			140 (methane)	141,124, 61,57	K-4
Monitor(O,S-dimethylphosphoramidothioate)	141	94	143,142, 125,111, 110,96, 95,92,80, 79,78,77, 65,64,63, 62,61,49, 40,32	142 (methane)	94	K-4 K-12

APPENDIX K (CONT.)

MASS SPECTRA OF PESTICIDES AND METABOLITES

COMPOUNDS/METABOLITES	MW	EI BASE m/z	OTHER EI m/z	CI BASE m/z	OTHER CI m/z	REFERENCE
Chlorfenvinphos	358	267	325,323, 295,269, 170,109	359 (isobutane)	363,361, 155,109	K-3,8
Demeton	258	88	170,143, 126,115, 112,109, 97,93	259 (isobutane)	171	K-3,1
Demeton-S-methyl	230	88	230,142, 125,109, 93	231 (isobutane)	169,143, 111	K-3,8
Demeton-S-methylsulfon	262	169	142,125, 109,93	263	121	K-3,8
Demeton-S-methylsulfoxid	246	109	168,142, 125,110, 93			K-3
Methidathion	302	145	180,172, 125,109, 93	145 (isobutane)	159,147	K-3,8
Trichlorfon	256	109	145,139, 112,110, 93	111 (isobutane)	261,259, 257	K-3,8
Warfarin	308	265	308,266, 147,145, 131,187, 121,103, 77,93			K-5

APPENDIX K (Cont.)

MASS SPECTRA OF PESTICIDES AND METABOLITES

COMPOUNDS/METABOLITES	MW	EI BASE m/z	OTHER EI m/z	CI BASE m/z	OTHER CI m/z	REFERENCE
Methoprene	310	73	278,251, 221,153, 137,111, 109,95, 81,69, 57,55, 43			K-9
Methylester of Methoprene	296	111	296,278, 236,221, 203,191, 153,109, 95,81, 69,59, 57,55, 43			K-9
Methylester of Methoprene	268	125	221,203, 175,147, 109,95, 81,69, 59,57, 55,43			K-9
Methylester of Methoprene	282	73	267,250, 235,218, 207,191, 175,125, 109,95, 81,69, 57,55			K-9

APPENDIX K (Cont.)

MASS SPECTRA OF PESTICIDES AND METABOLITES

COMPOUNDS/METABOLITES	MW	EI BASE m/z	OTHER EI m/z	CI BASE m/z	OTHER CI m/z	REFERENCE
Methylester of Methoprene	296	73	264,251, 221,139, 111,109, 95,81, 69,57, 55			K-9
Methylester of Methoprene	216	73	201,185, 169,153, 109,95, 81,69, 57,55, 43			K-9
Methylester of Methoprene	282	139	282,264, 249,221, 203,175, 111,109, 95,81, 69,59, 57,55, 43			K-9
0,0-Diethyl-0-(2,5-dichlorophenyl) phosphorothioate	315	223	281,279, 251,225, 164,162, 125,109, 93			K-6
0,0-Diethyl-0-(3,6-dichloro-2-pyridyl)-phosphorothioate	315	164	282,280, 252,226, 224,210, 176,174, 166,128, 97			K-6

APPENDIX K (Cont.)

MASS SPECTRA OF PESTICIDES AND METABOLITES

COMPOUNDS/METABOLITES	MW	EI BASE m/z	OTHER EI m/z	CI BASE m/z	OTHER CI m/z	REFERENCE
RO-20458 [1-(4'-ethylphenoxy)-3,7-dimethyl-6,7-epoxy-trans-2-octene]	274	71	153,122, 107,93			K-10
RO-20458-2,3-epoxide [1- 4'-ethylphenoxy -3,7-(dimethyl-2,3,6,7-diepoxyoctane]	228	107	122,93, 71			K-10
Metabolite of RO-20458	290	71	153,123, 119,95, 83,72			K-10
Amidithion	273	125	273,215, 199,171, 143,131			K-3
Formothion	257	93	257,224, 198,170, 143,126, 125			K-3
Trithionmethyl	314	157	314,159, 125,121, 93			K-3
Diozathion	456	97	270,197, 153,125, 121,109, 93			K-3
Disulfoton	274	88	274,186, 153,142, 125,121, 109,97, 93			K-3

APPENDIX K (Cont.)

MASS SPECTRA OF PESTICIDES AND METABOLITES

COMPOUNDS/METABOLITES	MW	EI BASE m/z	OTHER EI m/z	CI BASE m/z	OTHER CI m/z	REFERENCE
Ethion [(0,0,0,0 -Tetraethyl-S-methylene-bis-(phosphorodithioate)]	384	323	153,125, 121,109, 97,93			K-3,5
Phusalon	367	182	367,217, 186,184, 125,121, 109,97, 93			K-3
Abate	466	203	466,435, 360,344, 263,125, 109,93			K-3
Chlorthion	297	109	299,297, 125,93			K-3
Dicapthon	297	262	216,125, 109,93			K-3
Coumaphos	263	362	364,334, 304,228, 125,109, 97			K-3
Sulfotepp [(tetraethylpyrophosphorothionate)]	322	322	294,266, 238,202, 174,125, 121,97, 93			K-3,5

APPENDIX K (Cont.)

MASS SPECTRA OF PESTICIDES AND METABOLITES

COMPOUNDS/METABOLITES	MW	EI BASE m/z	OTHER EI m/z	CI BASE m/z	OTHER CI m/z	REFERENCE
Zinophos	248	96	192,175, 143,125, 121,107, 106,97, 93			K-3
Omethoate	213	110	156,125, 109,93			K-3
Tinox	216	110	142,136, 125,112, 109,93			K-3
Tetrachlorvinphos	364	109	333,331, 329,206, 204,93			K-3
Dimefox	154		154,110			K-3
Phoxim	298	103	104,76			K-3
Dibenzylnitrosamine	226			261 (NCI)	263,258, 194 (NCI)	K-11
Dimethylsulfate	126			80 (NCI)	112,111, 97,82(NCI)	K-11
trans-stilbene oxide	196			195	196,87, 86(NCI)	K-11
Benomyl	290			190 (NCI)	320,312, 293,289, 166(NCI)	K-11

APPENDIX K (Cont.)

MASS SPECTRA OF PESTICIDES AND METABOLITES

COMPOUNDS/METABOLITES	MW	EI BASE m/z	OTHER EI m/z	CI BASE m/z	OTHER CI m/z	REFERENCE
Captan	301			336 (NCI)	340,338, 334,300 (NCI)	K-11
S-methyl methylphosphonamidothioate F	125	78	126,125, 110,79, 64,63, 60,48, 47,46, 45			K-12
O-methyl-methylphosphordiamidothioate F	126	63	123,110, 96,95, 79,78, 64,68, 47			K-12
S-Methylphosphordiamidothioate A phosphondiamidothioate F	126	79	126,80, 64,63, 62,61, 47			K-12
O-Methyldiethylphosphinate F	136	79	136,108, 107,49, 48,47, 31,27, 26			K-12
Isopropylphosphondiamidothioate F	138	63	139,138, 96,95, 80,79, 78,47, 46,45, 41			K-12

APPENDIX K (Cont.)

MASS SPECTRA OF PESTICIDES AND METABOLITES

COMPOUNDS/METABOLITES	MW	EI BASE m/z	OTHER EI m/z	CI BASE m/z	OTHER CI m/z	REFERENCE
O-methyl-ethylphosphonamidothioate F	139	78	139,111, 110,80, 79,75, 64,63, 48,47, 46,45, 43,40			K-12
S-methyl-ethyl-phosphonamidothioate A	139	64	111,110, 93,92, 48,47, 46,45, 44,41, 40			K-12
O,O-dimethylphosphoramidothioate F	141	78	143,142, 141,111, 110,96, 95,94, 93,80, 79,77, 64,63, 49,48, 47,46, 45			K-12
O,S-dimethyl phosphoramidothioate	141	94	141,125, 111,95, 80,79, 64,47, 46,45, 32			

APPENDIX K (Cont.)

MASS SPECTRA OF PESTICIDES AND METABOLITES

COMPOUNDS/METABOLITES	MW	EI BASE m/z	OTHER EI m/z	CI BASE m/z	OTHER CI m/z	REFERENCE
O-methyl-diethylphosphinothioate A	152	124	154,153, 152,125, 123,196, 95,94, 92,91, 65,63, 48			K-12
O-methyl P-ethyl-N-methylphosphonamidothioate F	153	153	125,124, 123,96, 95,94, 93,92, 78,76, 63,62, 60,46, 45,43			K-12
O-methyl isopropyl-phosphonamidothioate F	153	78	154,153, 111,110, 95,80, 79,63, 62,48, 47,46, 44,42			K-12
S-methyl-isopropyl-phosphonamidothioate F	153	64	153,111, 110,107, 79,47, 46,43,41			K-12
S-methyl-n-propyl-phosphonamidothioate F	153	64	153,138, 125,111, 110,107, 79,47,46, 43,41			K-12

APPENDIX K (Cont.)

MASS SPECTRA OF PESTICIDES AND METABOLITES

COMPOUNDS/METABOLITES	MW	EI BASE m/z	OTHER EI m/z	CI BASE m/z	OTHER CI m/z	REFERENCE
0,0-dimethyl ethyl-phosphonothioate F	154	93	154,126, 125,123, 95,79, 63,47			K-12
0-S-Dimethyl ethyl-phosphonothioate F	154	79	126,125, 108,107, 59,47,			K-12
0,0,0-trimethyl phosphorothioate F	156	93	156,126, 125,97, 94,79, 63,47			K-12
Phenylphosphonic acid F	158	94	158,95, 78,77, 66,65, 51,50, 47			K-12
S-ethyl-P-ethyl-N-methyl phosphonamidothioate F	167	78	168,167, 152,139, 138,123, 110,109, 107,106, 94,81, 76,64, 63,62, 60,59, 49,47, 35			K-12

APPENDIX K (Cont.)

MASS SPECTRA OF PESTICIDES AND METABOLITES

COMPOUNDS/METABOLITES	MW	EI BASE m/z	OTHER EI m/z	CI BASE m/z	OTHER CI m/z	REFERENCE
O-methyl-n-butyl-phosphonamidothioate F	167	78	168,167, 138,136, 125,111, 110,95, 80,79, 77,64, 63,62, 47,46, 45			K-12
S-methyl-n-butyl-phosphonamidothioate F	167	64	167,152, 138,125, 121,120, 111,110, 79,57, 55,47, 46,41			K-12
O,O,-dimethyl-N,N-dimethyl-phosphoramidothioate F	169	44	169,138, 125,106, 93,79, 76,69, 63,47, 45			K-12
O,S-dimethyl-N,N-dimethyl-phosphoramidothioate F	169	44	169,131, 125,123, 122,121, 103,79, 77,69, 63,47, 46,45			K-12

MASS SPECTRA OF PESTICIDES AND METABOLITES

COMPOUNDS/METABOLITES	MW	EI BASE m/z	OTHER EI m/z	CI BASE m/z	OTHER CI m/z	REFERENCE
O,O-diethyl phosphioramidothioate F	169	80	169,144, 142,141, 125,124, 116,114, 113,108, 97,96, 92,65, 64,63, 48,47			K-12
O,S-diethyl phosphoramidothioate F	169	80	169,141, 140,125, 109,108, 97,96, 82,81, 64,62, 61,59, 48,47			K-12
Triethyl phosphate F	182	99	182,155, 139,138, 137,128, 126,109, 91,83, 82,81, 65,47			K-12
N-(dimethoxyphosphinothioyl) acetamidine F	182	182	184,183, 165,152, 135,125, 120,119, 110,94, 93,89, 79,78, 65,64, 47,46			K-12

APPENDIX K (Cont.)

MASS SPECTRA OF PESTICIDES AND METABOLITES

COMPOUNDS/METABOLITES	MW	EI BASE m/z	OTHER EI m/z	CI BASE m/z	OTHER CI m/z	REFERENCE
N-(methoxymethylthiophosphinyl) acetamidine F	182	93	182,167, 136,135, 125,110, 79,63, 47			K-12
O,O-dimethyl-N-acetylphosphoramidothioate F	183	143	184,183, 141,125, 112,111, 110,109, 104,95, 94,93, 80,78, 64,63, 47,46, 45,42, 41			K-12
O,S-dimethyl-N-acetylphosphoramidothioate F (Orthene F)	183	42	183,142, 136,125, 96,95, 94,80, 79,64, 62,48, 47,43			K-12

APPENDIX K (Cont.)

MASS SPECTRA OF PESTICIDES AND METABOLITES

COMPOUNDS/METABOLITES	MW	EI BASE m/z	OTHER EI m/z	CI BASE m/z	OTHER CI m/z	REFERENCE
0,0-diethyl-S-methyl-phorphorothioate A	184	93	185,184, 169,156, 140,139, 138,128, 112,111, 110,109, 97,91, 83,82, 81,65, 61,48, 47,45			K-12
0,0,S-trimethyl phophorotrithioate F	188	63	188,141, 109,95, 94,79, 77,64, 62,48, 47,46, 45,34, 33			K-12
0,0-diisopropyl phosphorothioric acid A	198	115	198,157, 156,141, 114,97, 59,54, 59,45, 43,42, 41,40, 39			K-12

APPENDIX K (Cont.)

MASS SPECTRA OF PESTICIDES AND METABOLITES

COMPOUNDS/METABOLITES	MW	EI BASE m/z	OTHER EI m/z	CI BASE m/z	OTHER CI m/z	REFERENCE
O-isopropyl-S-methyl ethylphosphonodithioate A	198	198	200,199, 156,140, 139,128, 111,110, 95,92, 80,76, 61,47, 46,45, 41,40, 39			K-12
0,0,0-triethyl-phosphorothioate F	198	121	198,170, 155,154, 144,143, 138,126, 125,115, 114,109, 97,93, 81,65, 47			K-12
0,0,S-triethyl-phosphorothioate F	198	93	198,170, 154,142, 138,126, 125,121, 111,110, 109,97, 83,82, 81,65			K-12

APPENDIX K (Cont.)

MASS SPECTRA OF PESTICIDES AND METABOLITES

COMPOUNDS/METABOLITES	MW	EI BASE m/z	OTHER EI m/z	CI BASE m/z	OTHER CI m/z	REFERENCE
N-(diethoxyphosphinothioyl) acetamidine F	210	133	210,182, 166,149, 119,108, 97,96, 92,80, 65,64, 63,47			K-12
N-(ethoxyethylthiophosphinyl) acetamidine F	210	80	210,182, 150,149, 121,108, 64,58, 47			K-12
0,0-diisopropyl-0-methyl-phosphorothioate A	212	129	212,171, 170,155, 128,111, 98,97, 59,44, 43,42			K-12
0,0-diisopropyl-S-methyl-phosphorothioate F	212	43	212,197, 170,165, 129,128, 111,83, 83,75,65, 59,47, 45,41, 39			K-12
p-methoxyphenyl-dimethyl-phosphate F	232	109	232,217, 124,123, 120,95,93, 92,81,79, 63,53, 41,39			K-12

APPENDIX K (Cont.)

MASS SPECTRA OF PESTICIDES AND METABOLITES

COMPOUNDS/METABOLITES	MW	EI BASE m/z	OTHER EI m/z	CI BASE m/z	OTHER CI m/z	REFERENCE
m-bromophenyl-phosphonic acid F	236/238	236/238	220,218, 174,172, 139,94, 93,92, 77,76, 75,74, 65,51, 50,48			K-12
O,O-diethyl-o-phenyl phosphorothioate F	246	94	246,218, 190,185, 174,172, 141,125, 110,109, 104,97, 81,77, 66,65, 63,51,47			K-12
O,S-diethyl O-phenyl phosphorothioate F	246	94	246,218, 190,185, 165,141, 125,110, 109,97, 95,77, 65,64, 63,51, 47			K-12

APPENDIX K (Cont.)

MASS SPECTRA OF PESTICIDES AND METABOLITES

COMPOUNDS/METABOLITES	MW	EI BASE m/z	OTHER EI m/z	CI BASE m/z	OTHER CI m/z	REFERENCE
0,0-diethyl S-phenyl phosphorothioate F	246	109	247,246, 218,190, 110,105, 104,97, 94,91, 81,66, 65,63, 51,45			K-12
0,0-dimethyl-S-phenyl phosphorothioate F	246	109	247,246, 218,190, 110,105, 104,97, 94,91, 81,66, 65,63, 51,45			K-12
0,0-dimethyl-0-p-methoxyphenyl phosphorothioate F	248	109	250,249, 248,154, 139,125, 124,123, 121,110, 93,81, 79,77, 65,64, 63,62, 47,44, 41			K-12
0,0-diethyl-0-p-methylphenyl	260	108	260,232, 215,204, 125,124, 109,107, 97,91, 79,77,65			K-12

APPENDIX K (Cont.)

MASS SPECTRA OF PESTICIDES AND METABOLITES

COMPOUNDS/METABOLITES	MW	EI BASE m/z	OTHER EI m/z	CI BASE m/z	OTHER CI m/z	REFERENCE
0,0-diethyl-S-p-methylphenyl phosphorothioate F	260	124	260,232, 205,152, 137,125, 123,121, 110,109, 97,91, 92,79, 77			K-12
0,S-diethyl-0-p-nitrophenyl phosphorothioate F	291	97	291,263, 155,139, 137,125, 123,97, 93,81, 65,63			K-12
Ethyl-p-nitrophenyl-phenylphosphonate (EPN oxon)A	307	142	307,306, 280,279, 278,262, 169,142, 77,65, 51			K-12
0,4-Bromo-2,5-dichlorophenyl-0-methyl phenylphosphonothioate (Leptophos)F	410	171	412,410, 379,377, 375,124, 98,78, 51,47			
4-Bromo-2,5-dichlorophenyl methyl phenylphosphonate (Leptophos oxon)	394	155	398,396, 394,363, 361,359, 359,97, 91,77,51			K-12

APPENDIX K (Cont.)

MASS SPECTRA OF PESTICIDES AND METABOLITES

COMPOUNDS/METABOLITES	MW	EI BASE m/z	OTHER EI m/z	CI BASE m/z	OTHER CI m/z	REFERENCE
1-(2,4,5-Trichlorobenzoyl)-2-(2,4,5-trichlorophenyl) glycerol	476	207	483,481, 479,477, 438,436, 434,432, 350,211, 209,183, 181,179, 172,170, 145,143, 135,133, 109,74			K-13
0-Ethyl-phenylphosphinate	170	78	170,142, 141,79			K-14
0-Benzyl-o-ethyl phenylphosphonothionate	292	91	292,157, 155,92			K-14

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APPENDIX L

HALOGENATED ORGANICS IDENTIFIED IN CHLORINATED WATERS

INTRODUCTION

Compounds listed in this appendix were derived from literature reports (through 1982) of compounds detected in various types of chlorinated waters. In most instances, mass spectral data were not available. Apparent molecular weight information obtained from unknowns detected in mutagenic residues using chemical ionization GC/MS was cross-referenced for molecular weight data in this table. If molecular weight information correlated, then attempts were made to compare EI mass spectra, if available (either literature, NBS library, or data generated from pure compounds). For those components that could not be compared to EI mass spectra or that were eliminated from consideration, candidate identifications are shown in Chapter IV, Table IV-26. Efforts will continue to obtain additional mass spectral data from publishers.

APPENDIX L

HALOGENATED ORGANICS IDENTIFIED IN CHLORINATED WATERS

COMPOUNDS	MW	EI BASE	OTHER EI	CI BASE	OTHER CI	REFERENCE
Chloromethane	50	50	52,49,47			L-4,28
Chloroethyne (Chloroacetylene)	60	60	62,59,47, 44,35,30, 28,25,24			L-4,28
Cyanogen chloride	61	61	63,35,30, 28,26			L-4,28
Vinyl chloride (Chloroethylene)	62	62	64,63,61, 27,26,25			L-4,28
Chloroethane (Ethyl Chloride)	64	27	66,64,51, 49,29,28, 26,25			L-4,28
2-chloropropane	78	43	80,78,65, 63,27			L-4,28
Dichloromethane (Methylene Chloride)	84	49	88,86,84, 51,47			L-4,23,28
Bromomethane	94	15	96,95,94, 93,81,79			L-4,28
Dichloroethyne (Dichloroacetylene)	94	94	98,96,59, 47,44,35, 23			L-4,28
1,1-dichloroethene (Vinylidene chloride)	96	61	98,96,63, 60,26			L-4,28
Cis-1,2-dichloroethylene	96	61	100,98, 96,64,60			L-4,28

APPENDIX L (Cont.)

HALOGENATED ORGANICS IDENTIFIED IN CHLORINATED WATERS

COMPOUNDS	MW	EI BASE	OTHER EI	CI BASE	OTHER CI	REFERENCE
Trans-1,2-dichloroethylene	96	61	100,98, 96,64,26			L-4,28
1,1-dichloroethane	98	63	100,98, 85,83,65, 28,27			L-4,28
1,2-dichloroethane	98	62	100,98, 64,63,51, 49,27			L-4,23,28
Dichlorofluoromethane	102	67	69,47,35			L-4,28
Bromoethyne	104		104,106			L-4
3-chloro-2-methylbut-1-ene	104	69	106,104, 89,70,68, 67,53,41, 39,26			L-11,28
Chloroisobutanol	108					L-18
Chlorobenzene	112	112	114,113, 77,51,50			L-4,26,28
Chlorocyclohexane	118	67	83,82,55, 54,41,39			L-11,26,28
Chloroform	118	83	87,85,49			L-3,11,21, 23,28
3-chloro-2-methylbutanol	122					L-18
N-bromodimethylamine	123					L-20

APPENDIX L (Cont.)

HALOGENATED ORGANICS IDENTIFIED IN CHLORINATED WATERS

COMPOUNDS	MW	EI BASE	OTHER EI	CI BASE	OTHER CI	REFERENCE
Dichlorobutane(i)	126					L-11,28
o-chlorotoluene	126					L-22,26
m-chlorotoluene	126					L-22,26
Bromochloromethane	128	49	132,130, 128,95, 93,51			L-4,28
4-chlorophenol	128	128	130,129, 100,65			L-14,15,16, 22,28
2-chlorophenol	128	128	130,129, 100,65, 38			L-15,28
2-chlorophenol	128	128	130,129, 100,92, 65,64,63			L-15,16,28
Dichloroacetic acid	128					L-18
Dichloronitromethane	129		83,30			L-4
Trichloroethylene	130	95 (130)	134,132, 99,97,62, 60,47,35, 25			L-4,18,27
Chloropyrone	130					L-21,22
Chloromaleic Anhydride	132					L-18

APPENDIX L (Cont.)

HALOGENATED ORGANICS IDENTIFIED IN CHLORINATED WATERS

COMPOUNDS	MW	EI BASE	OTHER EI	CI BASE	OTHER CI	REFERENCE
1,1,2-trichloroethane	132	97	134,132, 99,96,85, 83,61			L-4,28
1,1,1-trichloroethane	132	97	121,119, 117,99, 63,61,35, 22,21			L-4,23,28
Fluorotrichloromethane	136		101			L-4
Chlorodimethylbutanol	136					L-18
Chloroethylbenzene (isomer)	140	125	142,140, 127,105, 89,77,62, 51			L-11
Chlorobenzaldehyde	140					L-21,23
Iodomethane	142	142	141,127, 15			L-4,28
4-chloro-3-methylphenol	142					L-15
Trichloroallene	142					L-21
Bis(2-chloroethyl)ether	142					L-25
Chloroacetylfuran	144					L-21
Chlororesorcinol	144					L-15
1,4-dichlorobenzene	146	146	148,111, 75,74,50			L-4,11,28

APPENDIX L (Cont.)

HALOGENATED ORGANICS IDENTIFIED IN CHLORINATED WATERS

COMPOUNDS	MW	EI BASE	OTHER EI	CI BASE	OTHER CI	REFERENCE
1,3-dichlorobenzene	146	146	150,148, 111,75, 74,50			L-4,28
1,2-dichlorobenzene	146	146	150,110, 65			L-4,11,26, 28
Trichloropropane(i)	146					L-18,28
5-chlorouracil	146	146	148,112, 105,103, 78,76,60, 43,41,31, 29			L-4,11,15, 26,28
Chlorofumaric acid	150					L-18,28
Carbon Tetrachloride	152	117	121,119, 84,82,49, 47,37,35			L-4,28
N-bromoglycine	153					L-20
Chlorocumene	154					L-11
4-chlorobenzoic acid	156	139	158,156, 141,113, 111,75, 50			L-15,28
3-chlorobenzoic acid	156	139	158,156, 141,113, 111,77, 75			L-15,28

APPENDIX L (Cont.)

HALOGENATED ORGANICS IDENTIFIED IN CHLORINATED WATERS

COMPOUNDS	MW	EI BASE	OTHER EI	CI BASE	OTHER CI	REFERENCE
2-chlorobenzoic acid	156	139	158,156, 141,111, 75			L-15,28
Chloro-α-methyl benzyl alcohol	156	107	156,108, 79,77,51			L-11,28
4-chloro-2-methoxyphenol	158					L-14
Trichloroacrolein	158					L-18
Chlorotrihydroxybenzene	160					L-22
Dichlorotoluene	160	125	162,160 89,62			L-11,22,28
2,4-dichlorophenol	162	162	166,164 126,100, 99,98,63			L-14,17,21 22,28
2,6-dichlorophenol	162	162	166,164, 126,100, 99,98,63			L-21,22,28
2,5-dichlorophenol	162	162	166,164, 100,99,98, 63			L-14,17,21, 22,28
Trichloroacetic acid	162					L-18
Bromodichloromethane	162	83	129,127, 87,85,81, 79,49,48, 47,35			L-3,4,25, 39

APPENDIX L (Cont.)

HALOGENATED ORGANICS IDENTIFIED IN CHLORINATED WATERS

COMPOUNDS	MW	EI BASE	OTHER EI	CI BASE	OTHER CI	REFERENCE
Nitrotrichloromethane	163		117,30			L-4
Tetrachloroethylene	164	166	170,168, 164,133, 131,129, 96,94			L-4,28
Dichlorofurfural	164					L-18
Dichloromaleic anhydride	166	166	170,168, 124,122, 96,94,89, 58,47,43			L-18,28
Chloromethylisopropenylbenzene	166					L-22
1,1,2,2-tetrachloroethane	166	83	170,168, 166,133, 131,97, 96,95, 87,85			L-23,28
2-chloro-p-cymene	168	153	170,168, 155,117, 115,91			L-23,28
6-chloro-2-amino purine	169					L-15
4-chlorophenyl acetic acid	170	125	172,170, 121,91 89			L-15,28
Chloromalealic acid	170					L-22

APPENDIX L (Cont.)

HALOGENATED ORGANICS IDENTIFIED IN CHLORINATED WATERS

COMPOUNDS	MW	EI BASE	OTHER EI	CI BASE	OTHER CI	REFERENCE
Bis(2-chloroisopropyl)ether	170	45	121,79, 77,43,41, 39			L-25,28
Dibromomethane	172	174	176,172, 95,93,91, 81,79			L-4,28
3-chloro-5-hydroxy benzoic acid	172					L-15
3-chloro-4-hydroxy benzoic acid	172					L-14
5-chlorosalicylic acid	172					L-15
Chloroethyl catechol	172					L-22
p-bromophenol	172	174	175,173, 172,93, 88,86,65, 63,39,38			L-27,28
o-bromophenol	172	172	175,174, 173,93, 65,39			L-27,28
Dichloroxylene	174					L-22
Dichloroethylbenzene (isomer)	174	159	176,174. 161,141 139			L-11,18,28
2,5-dichloro-p-xylene	174	139	176,174, 141,103, 77,75,51			L-22,28

APPENDIX L (Cont.)

HALOGENATED ORGANICS IDENTIFIED IN CHLORINATED WATERS

COMPOUNDS	MW	EI BASE	OTHER EI	CI BASE	OTHER CI	REFERENCE
β-chloromuconic acid	176					L-23
Dichlororesorcinol	178					L-12
Dichlorocatechol	178					L-21,22,23
Tetrachloropropene	178					L-21
1,1,2,3-tetrachloro-2-propene	178					L-23
1,2,3,3-tetrachloropropene	178	143	182,180, 178,147, 145,85, 83			L-28
Dichloroformylthiophene	179					L-21,22
Trichlorobenzene (isomer)	180	180	184,182, 147,145, 109,74			L-11,28
Chloro-3-hydroxycymene	184					L-22
Chloro-8-hydroxycymene	184					L-21
Chlorocymene-α-ol	184					L-22
Phenoxyphenol	186					L-17
4-chloromandelic acid	186					L-15
8-chloroxanthine	186					L-15
Trichlorothiophene	186					L-21,22

APPENDIX L (Cont.)

HALOGENATED ORGANICS IDENTIFIED IN CHLORINATED WATERS

COMPOUNDS	MW	EI BASE	OTHER EI	CI BASE	OTHER CI	REFERENCE
p-bromoanisole	186					L-27
Trichloropentanone	188					L-18
Trichloropentanol-1	190					L-18
Dichloromethoxytoluene	190					L-11,18
Dichloro-α-methylbenzyl alcohol	191					L-11
Dichloroguaiacol	192					L-21,22,23
Trichlorotoluene (isomer)	194	159	196,194, 163,161, 123,61			L-21,22,28
Dichloroacetylthiophene	194					L-21,22
Tetrachloroacetone	194					L-18
1,1,3,3-tetrachloroacetone	194					L-11,22
5-bromoindole	195					L-27
2,4,6-trichlorophenol	196	196	200,198, 162,160, 134,132, 99,97			L-11,14, 17,22
2,4,5-trichlorophenol	196					L-11,14, 17,22
Trichloropyrone	198					L-21,22
Bromotrimethyl benzene	198					L-16

APPENDIX L (Cont.)

HALOGENATED ORGANICS IDENTIFIED IN CHLORINATED WATERS

COMPOUNDS	MW	EI BASE	OTHER EI	CI BASE	OTHER CI	REFERENCE
3,5,5-trichlorocyclopent-3-ene-1,2-dione	198					L-18
2-chlorofluorene	200					L-13
Dichloromethylisopropenylbenzene	200					L-22
Dichlorocymene	202					L-22
1-chloro-2,3,4-trimethoxybenzene	202	202	204,189, 187,168, 159,153, 146,144			L-23,28
3-chlorodibenzofuran	202					L-10
4-chlorophenyl phenyl ether	204	204	206,205, 141,77, 51			L-17,28
Bromonaphthalene	206					L-16
2,5-dichloro-4-methoxyanisole	206					L-17
Dichloroethyl catechol	206					L-22
Dichloroveratrole	206					L-22
3,5-dichloro-4-hydroxybenzoic acid	206					L-14
Chlorodibromomethane	206	129	210,208, 206,131, 127			L-3,4,11, 25,28
2,5-dichloro-3,6-dihydroxy-p-benzoquinone (chloranillic acid)	208					L-23

APPENDIX L (Cont.)

HALOGENATED ORGANICS IDENTIFIED IN CHLORINATED WATERS

COMPOUNDS	MW	EI BASE	OTHER EI	CI BASE	OTHER CI	REFERENCE
Bromotrichloroethene	208	129	208			L-4
Trichloroethylbenzene	208	193	212,210, 206,197, 195,175, 173			L-11,28
Tetrachloroisobutanol	208					L-18
Dichloropropionylthiophene	208					L-21
Trichloroxylene	208					L-22
N-methyltrichloroaniline	209					L-11
Dichloroiodomethane	210	83	210,175,			L-3,4
Bromotetralin	210					L-16
2,2-diphenylacetamide	211	167	211,168			L-2
Bromotetramethylbenzene	212					L-16
2-bromocymene(i)	212	197	214,212, 199,133, 119,118, 116			L-22,28
Trichlorocatechol	212					L-21,22,23
9-chlorophenanthrene	212					L-13
Trichlororesorcinol	212					L-12
1,1,2,3,3 pentachloropropene	212					L-21,23

APPENDIX L (Cont.)

HALOGENATED ORGANICS IDENTIFIED IN CHLORINATED WATERS

COMPOUNDS	MW	EI BASE	OTHER EI	CI BASE	OTHER CI	REFERENCE
Trichloroformylthiophene	214					L-21
Pentachloropropane	214					L-18
Chlorosyringaldehyde	216					L-22
Dichloro-8-hydroxycymene	217					L-11,21
Chloromethylpropylnaphthalene	218					L-22
Chlorodibenzo-p-dioxin	218					L-10
2,3-difluorodibenzo-p-dioxin	220	220	191,173, 164			L-8
Dichlorvos	220	109	220,187, 185,145, 97,93	220,221	225,223, 222,221, 187,185, 141,127, 109,60	L-6,19,24
Bromomethylnapthalene	220					L-16
Dichloropropylcatechol (isomer)	220					L-22
Tetrachlorothiophene	220					L-21
Trichloromethylstyrene (isomer)	220					L-11
2,4,6-trichlorocumene	222	207	226,224, 222,211, 210,209, 196,194, 173,171, 136			L-11,28

APPENDIX L (Cont.)

HALOGENATED ORGANICS IDENTIFIED IN CHLORINATED WATERS

COMPOUNDS	MW	EI BASE	OTHER EI	CI BASE	OTHER CI	REFERENCE
2-Methyl-3-chloro-5-hydroxynapththoquinone	222					L-17
Trichloro-N-methylanisole	224					L-11
Trichloro-α-methyl benzyl alcohol	224					L-11
N-bromoglutamate	225					L-20
2,3-dichloronapthoguinone	226					L-17
Trichloroguaiacol	226					L-21,22,23
1-methyl-9-chloro-phenanthrene	226					L-13
1-chloro-4-methyl-anthracene	226					L-13
8-chlorocaffeine	228					L-15
Bromocymene-α-ol	228					L-21
Pentachloroacetone	228					L-11,18
Trichloroacetylthiophene	228					L-21,22
Tetrachlorophenol	230					L-11,17,21
Bromobiphenyl	232					L-16
Chlorohydroxybenzophenone	232					L-25
Dichloro-bis-(ethoxy)benzene	234					L-11
Dichlorobutylcatechol	234					L-22
Bromodimethylnapththalene	234					L-16

APPENDIX L (Cont.)

HALOGENATED ORGANICS IDENTIFIED IN CHLORINATED WATERS

COMPOUNDS	MW	EI BASE	OTHER EI	CI BASE	OTHER CI	REFERENCE
Hexachloroethane	234					L-17
2,4-dichlorodibenzofuran	236					L-11
Trichloro-p-cymene	236					L-22
Trichlorodimethoxybenzene	240					L-11
Trichloroveratrole	240					L-22
Dichlorobromophenol	240					L-27
Tetrachloro-o-benzoquinone	244	218	250,248, 246,244, 220,216, 211,209, 192,190, 188,183, 181,155, 153,120, 118,44			L-22,23,28
Tetrachlorocatechol	246					L-21,33,23
Bromochloro-p-cymene	246					L-22
Bromotrimethylnaphthalene	248					L-16
Tetrachlorocyclohexanedione	248					L-17
4-bromodiphenylether	249	248	251,250, 249,169, 141,115, 77,51,50			L-17,28

APPENDIX L (Cont.)

HALOGENATED ORGANICS IDENTIFIED IN CHLORINATED WATERS

COMPOUNDS	MW	EI BASE	OTHER EI	CI BASE	OTHER CI	REFERENCE
2,4-dibromophenol	250					L-17,27
2,6-dibromophenol	250					L-17,27
2-hydroxy-3-chloro-fluoranthene	252					L-13
Bromoform	252	173	254,252, 175,171, 94,93,92, 91,81,80, 79			L-3,4,16 25,28
1,3-dichlorodibenzo-p-dioxin	252	252	254,217, 189,161, 126			L-8
2,3-dichlorodibenzo-p-dioxin	252	252	254,191, 189			L-8,10
2,7-dichlorodibenzo-p-dioxin	252	252	254,219, 217,191, 189,126, 75			L-10,28
Dichloromethylpropylnapthalene	254					L-22
Bromochloroiodomethane	254	127	254,175, 131,129, 50,48,47			L-3
Tetrachloromethoxytoluene	258					L-11
Pentachloroisopentanol	258					L-18
Tetrachloroguaiacol	260					L-21,22,23

APPENDIX L (Cont.)

HALOGENATED ORGANICS IDENTIFIED IN CHLORINATED WATERS

COMPOUNDS	MW	EI BASE	OTHER EI	CI BASE	OTHER CI	REFERENCE
Tetrachloro-4-methoxyphenol	260					L-17
Hexachloroacetone	262					L-11,18
Bromophenoxyphenol (isomer)	264					L-17
Dibromomethylphenol	264					L-27
Pentachlorophenol	264	266	270,268, 264,230, 202,200, 167,165, 132,130, 101,100, 95			L-17,22,28
2,4-dibromoanisole	264					L-27
Dichlorodimethylpropyldihydronaphthalene	268					L-22
1,1-methylene-bis(2-hydroxy-4-chlorobenzene)	268					L-17
Tetrachloroethylstyrene	269					L-11
Trimethoxytrichlorobenzene	270					L-22,23
1,2,4-trichlorodibenzofuran	270					L-10
Dibromoindole	273					L-27
Tetrachloro-4-methoxyanisole	274					L-17
5-chlorouridine	278					L-15

APPENDIX L (Cont.)

HALOGENATED ORGANICS IDENTIFIED IN CHLORINATED WATERS

COMPOUNDS	MW	EI BASE	OTHER EI	CI BASE	OTHER CI	REFERENCE
2,6-dibromo-4-methanal phenol	278					L-17
Pentachloroanisole	278					L-22,27
2,3-dichloro-7,8-dimethyldibenzo p-dioxin	280	280	282,267, 265			L-8
Hexachlorobenzene	282	284	290,288, 286,282, 251,249, 144,142, 107,71, 47			L-22,25,28
Chlorodibromophenol	284					L-27
2,3,7-trichlorodibenzo-p-dioxin	286	286 (288)	290,253, 251,225, 223			L-8,10
Dibromomethylindole	287					L-27
2,3-dichloro-7,8-difluoro dibenzo-p-dioxin	288	288	290,227, 225,162			L-8
Chlorthion	297	109	299,297, 125,93			L-6
Trimethoxytrichlorobenzaldehyde	298					L-21
Dibromoiodomethane	298	173	300,175, 171,139, 127,94, 93,92,91, 81,79			L-3

APPENDIX L (Cont.)

HALOGENATED ORGANICS IDENTIFIED IN CHLORINATED WATERS

COMPOUNDS	MW	EI BASE	OTHER EI	CI BASE	OTHER CI	REFERENCE
Chlorodiiodomethane	302	175	302,177, 127,50, 49,48,47			L-3
Tetrachlorodibenzofuran	304	303	304,302, 268,242, 240,207, 153			L-9,10
Dibromomethylbenzothiazole	305					L-27
1,3,6,8-Tetrachlorodibenzo-p-dioxin	320	322	326,324, 320,259, 257,196, 194,161, 160			L-10,28
2,3,6,7-tetrachlorodibenzo-p-dioxin	320					L-10
2,3,4,8-tetrachlorodibenzo-p-dioxin	320	322	326,324, 320,287, 285,259, 257,207, 194,161, 160,97, 78,57,56			L-8,10, 21,28, 39
1,2,3,4-Tetrachlorodibenzo-p-dioxin	320	322	324,320, 259,257, 194			L-8,10
1,3,7,8-tetrachlorodibenzo-p-dioxin	320	322	324,320, 287,285, 259,257, 194			L-8

APPENDIX L (Cont.)

HALOGENATED ORGANICS IDENTIFIED IN CHLORINATED WATERS

COMPOUNDS	MW	EI BASE	OTHER EI	CI BASE	OTHER CI	REFERENCE
4,6-dichloro-2-(2',4'- dichlorophenoxy)-phenol	322	146	328,326, 324,322, 288,286, 254,252, 223,150, 148			L-7
2,4,6-tribromophenol	328					L-17,27
Pentachlorodibenzofuran	338	340	344,342, 338,280, 278,275, 207,205, 173,171, 169			L-9,10
2,3-Dibromodibenzo-p-dioxin	340	342	344,340, 263,261, 182			L-8
Dibromophenoxyphenol (isomer)	342					L-17
2,4,6-tribromoanisole	342					L-27
Bromodiiodomethane	346	219	348,346, 254,221, 140,139, 128,127, 94,92,81, 79			L-3

APPENDIX L (Cont.)

HALOGENATED ORGANICS IDENTIFIED IN CHLORINATED WATERS

COMPOUNDS	MW	EI BASE	OTHER EI	CI BASE	OTHER CI	REFERENCE
Chlorpyrifos	349	197	349,316, 314,260, 258,199, 125,121, 109,97, 93			L-29,30
Tribromoindole	351					L-27
9,10-dichlorostearic acid	352					L-21,22,23
Pentachlorodibenzo-p-dioxin	354					L-10
Chlorfenvinphos	358	267	325,323, 295,269, 170,109	359	363,361, 155,109, 107	L-6,24
Bromophos	364	331	364,333, 329,125, 109,97, 93	367	369,365, 287,111	L-6,24
Tetrachlorvinphos	364	109	333,331, 329,206, 204,93			L-6
Tribromomethylindole	366					L-27
2,3-dibromo-7,8-dimethyl-dibenzo-p-dioxin	368	370	372,368, 357,355, 353,291, 289,210			L-8

APPENDIX L (Cont.)

HALOGENATED ORGANICS IDENTIFIED IN CHLORINATED WATERS

COMPOUNDS	MW	EI BASE	OTHER EI	CI BASE	OTHER CI	REFERENCE
Hexachlorodibenzofuran	372	374	380,378, 376,372, 311,309, 241,239, 187,186, 155			L-9
2,3-dibromo-7,8-difluro-dibenzo-p-dioxin	376	378	380,376, 299,297, 271,269, 218,188			L-8
1,2,3,7,8,9-hexachlorodibenzo-p-dioxin	388					L-10
Bromophos-ethyl	392	97	361,359, 331,329, 305,303, 301,242, 241,240, 125,121, 109,93	395	397,393, 139,111	L-6,24,29
Triiodomethane	394	267	394,254, 140,139, 127			L-3
2,3-dibromo-7,8-dichloro-dibenzo-p-dioxin	408	410	414,412, 408,349, 347,345, 304,303, 301			L-8
Heptachlorodibenzofuran	416		406			L-5

APPENDIX L (Cont.)

HALOGENATED ORGANICS IDENTIFIED IN CHLORINATED WATERS

COMPOUNDS	MW	EI BASE	OTHER EI	CI BASE	OTHER CI	REFERENCE
Tribromophenoxyphenol(isomer)	420					L-17
Tetrabromoindole	429					L-27
Heptachlorodibenzo-p-dioxin	432					L-10
Octachlorodibenzofuran	440	440				L-5
Tetrabromomethylindole	443					L-27
Octachlorodibenzo-p-dioxin	456	460	447,464, 462,458, 456,397, 395,334, 332,230			L-7
1-(2,4,5-trichlorobenzoyl)-2-(2,4,5-trichlorophenyl)glycerol	476	207	482,480, 478,476, 433,431, 429,427, 209,181, 179,172, 169,145, 143,109, 84,74			L-1
2,3,7,8-tetrabromodibenzo-p-dioxin	496	500	504,502, 498,496, 423,421			L-8
Tetrabromophenoxyphenol(isomer)	498					L-17
3,5,3',5'-tetrabromo-2',3-dihydroxydiphenylmethane	512					L-17

APPENDIX L (Cont.)

HALOGENATED ORGANICS IDENTIFIED IN CHLORINATED WATERS

COMPOUNDS	MW	EI BASE	OTHER EI	CI BASE	OTHER CI	REFERENCE
Pentabromophenoxyphenol	576					L-17
Hexabromophenoxyphenol	654					L-17

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M

SOIL CHARACTERISTICS OF WHITTIER NARROWS TEST BASIN

TABLE M-1

Geologic Soil Profile at Whittier Narrows Test Basin[a]

Depth Below Surface, Feet	Unit Thickness	From	To	Description
0	1 ft. 10 in.	0	1 ft. 10 in.	Dark brown very fine to medium silty sand and soil.
2	2 ft. 2 in.	1 ft. 10 in.	4 ft. 0 in.	Light brown to tan fine to medium sand with lenses of gray fine sand. Moist, oxidized, orange fine sand streaks in tan portion.
4	1 ft. 6 in.	4 ft. 0 in.	5 ft. 6 in.	Wood fragments up to 3 inches long in dark brown to black medium to fine sand. Sand is highly micaceous.
6	2 ft. 2 in.	5 ft. 6 in.	7 ft. 8 in.	Tan fine to medium soft, micaceous sand, with gray fine sand lenses. Tan portions show orange streaks of oxidized fine sand.
8	0 ft. 4 in.	7 ft. 8 in.	8 ft. 0 in.	Dark brown to black micaceous fine sandy silt stringer.
10	1 ft. 6 in.	8 ft. 0 in.	9 ft. 6 in.	Gray medium to coarse sand and "pea gravel" with occasional gravels to 3/8 in.

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[a] Los Angeles County Flood Control District (December 1962).

TABLE M-2

Physical Soil Characteristics at the Whittier Narrows Test Basin[a]

Depth (feet)	Mean Particle Size (mm)	Geometric Standard Deviation	Moisture Content[b]	Volatile Solids[c]	COD[d]
0	0.011	25.0	0.40	65	33
1.0	0.050	13.0		50	21
1.5	0.145	4.0	0.21	21	9
2.5	0.105	1.7		14	6
3.5	0.058	2.3	0.31	22	10
4.5	0.054	1.8		18	7
5.5	0.010	32.0	0.39	24	12
6.5	0.062	1.9		25	18
7.5	0.066	1.7	0.33	17	7
8.5	0.165	1.5		6	3

[a] Los Angeles County Flood Control District (December, 1962).
[b] Weight loss at 105°C, gm water per gm dry soil.
[c] Weight loss at 600°C, gm volatile solids per kg dry soil.
[d] Chemical oxygen demand, gm COD per kg dry soil.

N

ANNUAL RECLAIMED WATER ESTIMATES FOR 32 MONTEBELLO FOREBAY PURVEYORS

APPENDIX N

ANNUAL RECLAIMED WATER ESTIMATES FOR 32 MONTEBELLO FOREBAY WATER PURVEYORS

Purveyor: California Water Service Company (#1)*

Year	Subarea A			Subarea B			Subarea C			Subarea D			Subarea E		
	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)
1961	-	0	0	0	74	0	0	100	0	0	48	0	0	96	0
1962	-	0	0	0	75	0	0	100	0	0	48	0	0	88	0
1963	-	0	0	0	68	0	0	100	0	0	39	0	0	96	0
1964	-	0	0	0	55	0	0	100	0	0	27	0	0	86	0
1965	-	0	0	0	56	0	0	100	0	0	27	0	0	78	0
1966	-	0	0	0	52	0	0	100	0	0	28	0	0	75	0
1967	-	0	0	0	44	0	0	100	0	0	30	0	0	75	0
1968	-	0	0	0	33	0	<1	100	<1	0	22	0	<1	64	<1
1969	-	0	0	0	44	0	<1	100	<1	0	21	0	1	70	1
1970	-	0	0	0	41	0	<1	100	<1	0	21	0	1	44	<1
1971	-	0	0	0	47	0	<1	100	<1	0	25	0	1	59	1
1972	-	0	0	0	33	0	1	100	1	0	19	0	2	64	1
1973	-	0	0	0	33	0	2	100	2	0	20	0	3	68	2
1974	-	0	0	0	34	0	2	100	2	0	21	0	3	76	2
1975	-	0	0	0	34	0	3	100	3	0	18	0	3	70	2
1976	-	0	0	<1	30	<1	4	100	4	0	15	0	4	66	3
1977	-	0	0	<1	32	<1	6	100	6	0	24	0	7	76	5

* Numbers in () refer to Figure VI-2 in Chapter VI.

APPENDIX N (cont.)

Purveyor: Citrus Grove Heights Water Company (#2)

	Subarea A			Subarea B		
Year	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)
1961	0	100	0	0	100	0
1962	0	100	0	0	100	0
1963	2	100	2	2	100	2
1964	3	100	3	3	100	3
1965	3	100	3	3	100	3
1966	5	100	5	5	100	5
1967	6	100	6	6	100	6
1968	8	100	8	8	100	8
1969	8	100	8	8	100	8
1970	9	100	9	9	100	9
1971	0	0	0	14	100	14
1972	0	0	0	15	100	15
1973	0	0	0	14	100	14
1974	0	1	0	15	100	15
1975	0	1	0	18	100	18
1976	0	1	0	0	1	0
1977	3	10	<1	3	10	<1

APPENDIX N (cont.)

Purveyor: City of Downey (#3)

Year	Subarea A			Subarea B			Subarea C			Subarea D			Subarea E			Subarea F		
	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)
1961	0	100	0	0	100	0	0	100	0	0	100	0	0	100	0	0	100	0
1962	0	100	0	0	100	0	0	100	0	0	100	0	0	100	0	0	100	0
1963	0	100	0	0	19	0	0	53	0	0	100	0	0	100	0	<1	100	<1
1964	1	100	1	1	13	<1	2	30	1	2	100	2	<1	100	<1	3	100	3
1965	1	100	1	2	8	<1	2	60	1	2	100	2	2	100	2	2	100	2
1966	2	100	2	2	14	<1	2	77	2	2	100	2	2	100	2	2	100	2
1967	2	100	2	2	10	<1	3	81	2	4	100	4	2	100	2	4	100	4
1968	4	100	4	3	2	0	4	69	3	6	100	6	3	100	3	2	100	2
1969	7	100	7	3	16	<1	7	66	4	10	100	10	4	100	4	6	100	6
1970	6	100	6	2	20	<1	6	51	3	8	100	8	6	100	6	6	100	6
1971	11	100	11	5	12	1	9	67	6	13	100	13	4	100	4	11	100	11
1972	13	100	13	8	6	<1	10	56	5	15	100	15	6	100	6	7	100	7
1973	18	100	18	13	16	2	13	61	8	22	100	22	7	100	7	11	100	11
1974	14	100	14	10	23	2	11	84	9	15	100	15	17	100	17	11	100	11
1975	14	100	14	9	38	4	11	100	11	15	100	15	11	100	11	9	100	9
1976	16	100	16	13	26	3	14	97	14	17	100	17	15	100	15	11	100	11
1977	22	100	22	18	50	9	19	100	19	22	100	22	14	100	14	14	100	14

APPENDIX N (cont.)

Purveyor: Downey Valley Water Company (#4)

Year	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)
1961	0	100	0
1962	0	100	0
1963	< 1	100	< 1
1964	2	100	2
1965	2	100	2
1966	2	100	2
1967	2	100	2
1968	3	100	3
1969	6	100	6
1970	4	100	4
1971	8	100	8
1972	9	100	9
1973	12	100	12
1974	9	100	9
1975	9	100	9
1976	12	100	12
1977	16	100	16

APPENDIX N (cont.)

Purveyor: Laguna Maywood Mutual Water Company (#5)

Year	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)*
1961	0	100	0
1962	0	100	0
1963	0	55	0
1964	0	41	0
1965	0	50	0
1966	0	47	0
1967	2	49	0
1968	3	45	0
1969	3	38	0
1970	4	45	0
1971	5	43	0
1972	11	52	0
1973	8	50	0
1974	14	61	0
1975	17	60	0
1976	23	76	0
1977	15	85	0

* Area is industrial - no reclaimed water in residential supply.

Purveyor: La Habra Heights Water Company District (#6)

Year	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)
1961	0	100	0
1962	0	100	0
1963	< 1	100	< 1
1964	3	100	3
1965	4	100	4
1966	4	100	4
1967	5	100	5
1968	6	100	6
1969	10	100	10
1970	7	100	7
1971	12	100	12
1972	14	100	14
1973	21	100	21
1974	15	100	15
1975	15	100	15
1976	17	100	17
1977	23	100	23

Purveyor: Los Nietos Mutual Well Owners Association (#7)

Year	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)
1961	0	100	0
1962	0	100	0
1963	< 1	100	< 1
1964	3	100	3
1965	4	100	4
1966	4	100	4
1967	5	100	5
1968	6	100	6
1969	10	100	10
1970	8	100	8
1971	16	100	16
1972	17	100	17
1973	23	100	23
1974	15	100	15
1975	15	100	15
1976	17	100	17
1977	23	100	23

APPENDIX N (cont.)

Purveyor: City of Montebello (#8)

Year	Subarea A % Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)*	Subarea B % Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)	Subarea C % Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)**
1961	0	100	0	-	0	0	0	100	0
1962	0	100	0	-	0	0	0	100	0
1963	0	100	0	-	0	0	0	100	0
1964	2	100	2	-	0	0	< 1	99	0
1965	2	100	2	-	0	0	8	33	0
1966	3	100	3	-	0	0	9	24	0
1967	3	100	3	-	0	0	8	22	0
1968	4	100	4	-	0	0	7	20	0
1969	7	100	7	-	0	0	9	20	0
1970	6	100	6	-	0	0	14	16	0
1971	9	100	9	-	0	0	10	19	0
1972	11	100	11	-	0	0	16	40	0
1973	16	100	16	-	0	0	17	34	0
1974	12	100	12	-	0	0	23	10	0
1975	14	100	14	-	0	0	15	3	0
1976	17	100	17	-	0	0	15	5	0
1977	23	100	23	-	0	0	17	17	0

* Area development did not begin until 1972

** Entire area is industrial

Purveyor: Montebello Land and Water Company (#9)

Year	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)
1961	0	100	0
1962	0	100	0
1963	0	100	0
1964	0	100	0
1965	0	100	0
1966	2	100	2
1967	3	100	3
1968	3	100	3
1969	3	100	3
1970	4	100	4
1971	8	100	8
1972	6	100	6
1973	11	100	11
1974	13	100	13
1975	19	100	19
1976	13	100	13
1977	13	100	13

APPENDIX N (cont.)

Purveyor: City of Norwalk (#10)

Year	Subarea A % Reclaimed Pumped (Pr)	 % Ground-water in total supply (G)	 % Reclaimed in total supply (Tr)	Subarea B % Reclaimed Pumped (Pr)	 % Ground-water in total supply (G)	 % Reclaimed in total supply (Tr)	Subarea C % Reclaimed Pumped (Pr)	 % Ground-water in total supply (G)	 % Reclaimed in total supply (Tr)	Subarea D % Reclaimed Pumped (Pr)	 % Ground-water in total supply (G)	 % Reclaimed in total supply (Tr)
1961	0	83	0	0	83	0	0	100	0	0	100	0
1962	0	80	0	0	80	0	0	100	0	0	100	0
1963	1	81	1	1	81	1	0	100	0	0	100	0
1964	2	90	2	2	90	2	0	100	0	0	100	0
1965	2	87	2	2	87	2	0	100	0	0	100	0
1966	3	100	3	3	90	2	0	100	0	0	100	0
1967	2	100	2	4	94	4	0	100	0	0	100	0
1968	4	100	4	5	98	5	0	100	0	0	100	0
1969	3	100	3	8	100	8	0	100	0	0	100	0
1970	5	100	5	8	72	6	1	100	1	0	100	0
1971	5	100	5	13	81	10	1	100	1	0	100	0
1972	8	100	8	16	77	12	2	100	2	0	100	0
1973	7	100	7	21	64	13	2	100	2	0	100	0
1974	9	100	9	15	60	9	3	100	3	0	100	0
1975	14	100	14	16	52	8	5	100	5	0	100	0
1976	15	100	15	19	51	10	4	100	4	0	100	0
1977	17	100	17	23	58	13	7	100	7	0	100	0

APPENDIX N (cont.)

Purveyor: Orchard Dale County Water District (#11)

	Subarea A			Subarea B		
Year	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)
1961	0	100	0	-	0	0
1962	0	100	0	-	0	0
1963	0	72	0	-	0	0
1964	3	81	2	-	0	0
1965	4	84	3	-	0	0
1966	4	83	4	-	0	0
1967	5	74	3	-	0	0
1968	6	72	4	-	0	0
1969	10	79	8	-	0	0
1970	7	83	6	-	0	0
1971	12	79	10	-	0	0
1972	14	66	9	-	0	0
1973	21	87	18	-	0	0
1974	15	99	15	-	0	0
1975	15	82	12	-	0	0
1976	17	97	17	-	0	0
1977	23	85	20	-	0	0

APPENDIX N (cont.)

Purveyor: Park Water Company (#12)

Year	Subarea A			Subarea B			Subarea C			Subarea D		
	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)
1961	0	100	0	0	100	0	0	100	0	0	100	0
1962	0	100	0	0	100	0	0	100	0	0	100	0
1963	0	100	0	0	100	0	0	100	0	0	100	0
1964	0	99	0	0	100	0	0	100	0	0	100	0
1965	< 1	33	< 1	0	100	0	0	100	0	0	100	0
1966	1	24	< 1	0	100	0	0	100	0	0	100	0
1967	1	22	< 1	0	100	0	0	100	0	0	100	0
1968	1	20	< 1	0	100	0	0	100	0	0	100	0
1969	2	20	< 1	0	100	0	0	100	0	0	100	0
1970	6	16	1	0	100	0	< 1	100	< 1	< 1	100	< 1
1971	4	19	1	1	100	1	< 1	35	< 1	< 1	100	< 1
1972	8	40	3	2	100	2	1	9	0	1	100	1
1973	13	46	6	2	100	2	2	4	0	2	100	2
1974	20	52	10	3	100	3	3	4	0	3	100	3
1975	15	60	9	3	100	3	6	4	0	6	100	6
1976	15	54	8	6	100	6	5	0	0	5	100	5
1977	17	62	11	5	100	5	7	12	0	7	100	7

APPENDIX N (cont.)

Purveyor: Park Water Company cont. (#12)

Year	Subarea E % Reclaimed Pumped (Pr)	Subarea E % Ground-water in total supply (G)	Subarea E % Reclaimed in total supply (Tr)	Subarea F % Reclaimed Pumped (Pr)	Subarea F % Ground-water in total supply (G)	Subarea F % Reclaimed in total supply (Tr)	Subarea G % Reclaimed Pumped (Pr)	Subarea G % Ground-water in total supply (G)	Subarea G % Reclaimed in total supply (Tr)	Subarea H % Reclaimed Pumped (Pr)	Subarea H % Ground-water in total supply (G)	Subarea H % Reclaimed in total supply (Tr)
1961	0	100	0	0	100	0	0	100	0	0	100	0
1962	0	100	0	0	1	0	0	96	0	0	100	0
1963	0	82	0	0	0	0	0	64	0	0	95	0
1964	0	67	0	0	0	0	0	70	0	0	96	0
1965	0	66	0	0	0	0	0	65	0	0	96	0
1966	0	65	0	0	0	0	0	82	0	0	98	0
1967	0	67	0	0	6	0	0	89	0	0	99	0
1968	0	69	0	0	2	0	0	64	0	0	99	0
1969	0	68	0	0	0	0	0	60	0	0	100	0
1970	< 1	67	< 1	< 1	3	0	< 1	52	0	< 1	99	< 1
1971	< 1	62	< 1	< 1	0	0	< 1	36	< 1	< 1	89	< 1
1972	1	61	< 1	1	4	0	1	52	< 1	1	89	1
1973	2	49	1	1	0	0	1	64	< 1	1	95	1
1974	3	43	1	1	17	< 1	1	47	< 1	1	96	1
1975	6	76	5	2	31	1	2	71	1	2	100	2
1976	5	91	5	3	5	0	3	70	2	3	100	3
1977	7	93	7	3	0	0	3	92	3	3	100	3

APPENDIX N (cont.)

Purveyor: Pico County Water District (#13)

Year	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)
1961	0	100	0
1962	0	100	0
1963	1	100	1
1964	2	100	2
1965	3	100	3
1966	4	100	4
1967	4	100	4
1968	5	100	5
1969	7	100	7
1970	6	100	6
1971	10	100	10
1972	12	100	12
1973	17	100	17
1974	15	100	15
1975	16	100	16
1976	16	100	16
1977	15	100	15

APPENDIX N (cont.)

Purveyor: City of Pico Rivera (#14)

Year	Subarea A % Reclaimed Pumped (Pr)	Subarea A % Ground-water in total supply (G)	Subarea A % Reclaimed in total supply (Tr)	Subarea B % Reclaimed Pumped (Pr)	Subarea B % Ground-water in total supply (G)	Subarea B % Reclaimed in total supply (Tr)	Subarea C % Reclaimed Pumped (Pr)	Subarea C % Ground-water in total supply (G)	Subarea C % Reclaimed in total supply (Tr)	Subarea D % Reclaimed Pumped (Pr)*	Subarea D % Ground-water in total supply (G)	Subarea D % Reclaimed in total supply (Tr)	Subarea E % Reclaimed Pumped (Pr)	Subarea E % Ground-water in total supply (G)	Subarea E % Reclaimed in total supply (Tr)
1961	0	100	0	0	100	0	0	100	0	-	100	0	0	100	0
1962	0	100	0	0	100	0	0	100	0	-	100	0	0	100	0
1963	0	100	0	0	100	0	0	100	0	-	100	0	0	100	0
1964	1	100	1	2	100	2	2	100	2	-	100	0	< 1	100	< 1
1965	1	100	1	2	100	2	2	100	2	-	100	0	2	100	2
1966	2	100	2	3	100	3	3	100	3	-	100	0	2	100	2
1967	3	100	3	4	100	4	4	100	4	-	100	0	2	100	2
1968	5	100	5	5	100	5	5	100	5	-	100	0	3	100	3
1969	9	100	9	8	100	8	8	100	8	-	100	0	5	100	5
1970	7	71	5	9	85	8	9	100	9	-	100	0	6	100	6
1971	14	16	2	14	100	14	14	100	14	-	100	0	6	100	6
1972	17	6	1	11	56	6	11	100	11	-	100	0	8	100	8
1973	23	2	< 1	16	2	< 1	16	100	16	-	100	0	10	100	10
1974	15	4	1	15	4	1	15	100	15	-	100	0	17	100	17
1975	15	4	1	18	4	1	18	100	18	-	100	0	12	100	12
1976	17	9	2	14	9	1	14	100	14	-	100	0	16	100	16
1977	23	1	< 1	13	100	13	13	100	13	-	100	0	16	100	16

* Not determined - Area is entirely commercial and industrial, no reclaimed water in residential supply.

APPENDIX N (cont.)

Purveyor: San Gabriel Valley Water Company (#15)

Year	Subarea A % Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)	Subarea B % Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)	Subarea C % Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)	Subarea D % Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)
1961	-	0	0	0	100	0	0	100	0	0	100	0
1962	-	0	0	0	100	0	0	100	0	0	100	0
1963	-	0	0	0	100	0	5	100	5	4	100	4
1964	-	0	0	2	100	2	6	100	6	5	100	5
1965	-	0	0	3	100	3	5	100	5	5	100	5
1966	-	0	0	3	0	0	6	100	6	5	100	5
1967	-	0	0	0	0	0	7	100	7	6	100	6
1968	-	0	0	0	0	0	12	100	12	10	100	10
1969	-	0	0	0	0	0	9	100	9	9	100	9
1970	-	0	0	0	0	0	14	0	0	12	100	12
1971	-	0	0	11	0	0	16	0	0	15	100	15
1972	-	0	0	0	0	0	0	0	0	20	100	20
1973	-	0	0	0	0	0	0	0	0	16	100	16
1974	-	0	0	0	0	0	0	0	0	15	100	15
1975	-	0	0	15	0	0	0	0	0	17	100	17
1976	-	0	0	0	0	0	0	0	0	22	100	22
1977	-	0	0	23	49	11	0	0	0	22	100	22

APPENDIX N (cont.)

Purveyor: City of Santa Fe Springs (#16)

	Subarea A			Subarea B		
Year	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)*	% Reclaimed in total supply (Tr)
1961	0	83	0	-	-	0
1962	0	80	0	-	-	0
1963	1	81	1	-	-	0
1964	2	90	2	-	-	0
1965	2	87	2	-	-	0
1966	3	90	2	-	-	0
1967	4	94	4	-	-	0
1968	5	98	5	-	-	0
1969	8	100	8	-	-	0
1970	8	72	6	-	-	0
1971	13	81	10	-	-	0
1972	16	77	12	-	-	0
1973	20	64	13	-	-	0
1974	15	60	9	-	-	0
1975	16	52	8	-	-	0
1976	19	51	10	-	-	0
1977	22	58	13	-	-	0

* Undetermined - Entire area is industrial, no reclaimed water in residential supply.

APPENDIX N (cont.)

Purveyor: South Montebello Irrigation District (#17)

Year	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)
1961	0	100	0
1962	0	100	0
1963	0	100	0
1964	4	100	4
1965	5	100	5
1966	5	100	5
1967	6	100	6
1968	8	100	8
1969	13	100	13
1970	10	100	10
1971	16	100	16
1972	17	100	17
1973	23	100	23
1974	15	100	15
1975	15	100	15
1976	17	100	17
1977	23	100	23

APPENDIX N (cont.)

Purveyor: Southern California Water Company (#18)

Year	Subarea A % Reclaimed Pumped (Pr)	Subarea A % Ground-water in total supply (G)	Subarea A % Reclaimed in total supply (Tr)	Subarea B % Reclaimed Pumped (Pr)	Subarea B % Ground-water in total supply (G)	Subarea B % Reclaimed in total supply (Tr)	Subarea C % Reclaimed Pumped (Pr)	Subarea C % Ground-water in total supply (G)	Subarea C % Reclaimed in total supply (Tr)	Subarea D % Reclaimed Pumped (Pr)	Subarea D % Ground-water in total supply (G)	Subarea D % Reclaimed in total supply (Tr)
1961	0	93	0	0	100	0	0	99	0	0	27	0
1962	0	91	0	0	100	0	0	99	0	0	4	0
1963	0	32	0	0	100	0	0	46	0	0	0	0
1964	1	50	< 1	< 1	100	< 1	2	38	1	0	0	0
1965	1	40	< 1	< 1	100	< 1	2	51	1	0	0	0
1966	1	35	< 1	1	100	1	2	46	1	0	0	0
1967	1	50	< 1	1	100	1	2	51	1	0	0	0
1968	2	56	1	2	100	2	2	60	1	0	0	0
1969	4	47	2	3	100	3	3	44	1	0	0	0
1970	3	36	1	3	100	3	2	54	1	0	0	0
1971	6	39	2	6	100	6	3	46	2	0	0	0
1972	8	59	5	8	100	8	4	57	2	0	0	0
1973	8	46	4	11	100	11	5	48	2	0	0	0
1974	6	28	2	8	84	7	6	41	2	0	0	0
1975	7	24	2	8	56	5	4	47	2	0	0	0
1976	7	9	1	10	31	3	9	69	6	0	0	0
1977	11	14	2	15	100	15	13	80	10	0	0	0

APPENDIX N (cont.)

Purveyor: Southern California Water Company cont. (#18)

Year	Subarea E % Reclaimed Pumped (Pr)	 % Ground-water in total supply (G)	 % Reclaimed in total supply (Tr)	Subarea F % Reclaimed Pumped (Pr)	 % Ground-water in total supply (G)	 % Reclaimed in total supply (Tr)	Subarea G % Reclaimed Pumped (Pr)	 % Ground-water in total supply (G)	 % Reclaimed in total supply (Tr)
1961	0	100	0	0	100	0	0	100	0
1962	0	100	0	0	100	0	0	98	0
1963	0	100	0	0	100	0	0	44	0
1964	0	100	0	0	100	0	0	37	0
1965	0	100	0	0	100	0	0	33	0
1966	0	100	0	0	100	0	0	49	0
1967	0	100	0	0	100	0	0	62	0
1968	< 1	100	< 1	0	100	0	0	62	0
1969	< 1	100	< 1	1	100	1	1	56	< 1
1970	< 1	100	< 1	1	100	1	1	51	< 1
1971	< 1	100	< 1	1	100	1	1	53	< 1
1972	< 1	100	< 1	1	100	1	1	39	< 1
1973	1	100	1	1	100	1	1	57	< 1
1974	1	100	1	2	100	2	2	68	1
1975	< 1	100	< 1	2	100	2	2	100	2
1976	< 1	100	< 1	4	100	4	4	75	3
1977	< 1	100	< 1	4	100	4	4	99	4

APPENDIX N (cont.)

Purveyor: Southwest Suburban Water Co. (#19)

Year	Subarea A % Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)	Subarea B % Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)
1961	-	0	0	0	38	0
1962	-	0	0	0	54	0
1963	-	0	0	0	28	0
1964	-	0	0	0	27	0
1965	-	0	0	< 1	32	< 1
1966	-	0	0	< 1	30	< 1
1967	-	0	0	1	13	< 1
1968	-	0	0	1	14	< 1
1969	-	0	0	1	25	< 1
1970	-	0	0	3	14	< 1
1971	-	0	0	2	9	< 1
1972	-	0	0	4	23	1
1973	-	0	0	6	21	1
1974	-	0	0	8	15	1
1975	-	0	0	6	8	< 1
1976	-	0	0	6	0	0
1977	-	0	0	8	0	0

Purveyor: City of Whittier (#20)

Year	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)
1961	0	1	0
1962	0	1	0
1963	1	9	< 1
1964	0	0	0
1965	0	0	0
1966	0	0	0
1967	0	0	0
1968	0	0	0
1969	0	0	0
1970	0	0	0
1971	0	0	0
1972	0	0	0
1973	0	0	0
1974	0	1	0
1975	0	1	0
1976	0	1	0
1977	3	10	< 1

APPENDIX N (cont.)

Purveyor: Century Center Mutual Water Association (#21)

Year	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)
1961	0	100	0
1962	0	100	0
1963	0	100	0
1964	0	100	0
1965	0	100	0
1966	0	100	0
1967	0	100	0
1968	0	100	0
1969	1	100	1
1970	1	100	1
1971	1	100	1
1972	1	100	1
1973	1	100	1
1974	3	100	3
1975	2	100	2
1976	5	100	5
1977	6	100	6

Purveyor: Century City Mutual Water Company (#22)

Year	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)
1961	0	100	0
1962	0	100	0
1963	0	100	0
1964	0	100	0
1965	0	100	0
1966	0	100	0
1967	0	100	0
1968	0	100	0
1969	0	100	0
1970	0	100	0
1971	0	100	0
1972	0	100	0
1973	0	100	0
1974	0	100	0
1975	0	100	0
1976	0	100	0
1977	0	100	0

Purveyor: Chansal Mutual Water Company (#23)

Year	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)
1961	0	100	0
1962	0	100	0
1963	0	100	0
1964	0	100	0
1965	0	100	0
1966	0	100	0
1967	0	100	0
1968	0	100	0
1969	0	100	0
1970	1	100	1
1971	2	100	2
1972	2	100	2
1973	3	100	3
1974	5	100	5
1975	9	100	9
1976	7	100	7
1977	13	100	13

APPENDIX N (cont.)

Purveyor: City of Lynwood (#24)

Year	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)
1961	0	100	0
1962	0	100	0
1963	0	73	0
1964	0	62	0
1965	0	57	0
1966	0	74	0
1967	0	61	0
1968	0	69	0
1969	0	59	0
1970	0	48	0
1971	0	53	0
1972	0	68	0
1973	0	71	0
1974	< 1	99	< 1
1975	< 1	100	< 1
1976	< 1	93	< 1
1977	< 1	100	< 1

Purveyor: Maywood Mutual Water
Company(#25)

Year	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)
1961	0	100	0
1962	0	100	0
1963	0	100	0
1964	0	68	0
1965	0	43	0
1966	0	54	0
1967	0	83	0
1968	0	74	0
1969	0	76	0
1970	0	92	0
1971	0	100	0
1972	0	99	0
1973	0	99	0
1974	0	100	0
1975	0	100	0
1976	0	96	0
1977	0	97	0

APPENDIX N (cont.)

Purveyor: Peerless Land and Water Company (#26)

Year	Subarea A % Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)	Subarea B % Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)	Subarea C % Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)	Subarea D % Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)
1961	0	100	0	0	100	0	0	100	0	0	100	0
1962	0	100	0	0	100	0	0	100	0	0	100	0
1963	0	100	0	0	100	0	0	100	0	0	100	0
1964	0	100	0	0	100	0	0	100	0	0	100	0
1965	0	100	0	0	100	0	0	100	0	0	100	0
1966	0	100	0	0	100	0	0	100	0	0	100	0
1967	0	100	0	0	100	0	0	100	0	0	100	0
1968	0	100	0	0	100	0	0	100	0	0	100	0
1969	0	100	0	0	100	0	0	100	0	0	100	0
1970	0	100	0	0	100	0	1	100	1	0	100	0
1971	0	100	0	0	100	0	1	100	1	0	24	0
1972	0	100	0	0	100	0	2	100	2	0	23	0
1973	0	100	0	0	100	0	2	100	2	0	15	0
1974	0	100	0	1	100	1	2	100	2	0	21	0
1975	2	100	2	2	100	2	4	100	4	0	18	0
1976	3	100	3	2	100	2	3	100	3	< 1	17	< 1
1977	3	100	3	3	100	3	4	100	4	< 1	24	< 1

APPENDIX N (cont.)

Purveyor: Pomering Tract Water Association (#27)

Year	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)
1961	0	100	0
1962	0	100	0
1963	0	100	0
1964	0	100	0
1965	0	100	0
1966	0	100	0
1967	0	100	0
1968	0	100	0
1969	0	100	0
1970	2	20	< 1
1971	5	12	< 1
1972	8	6	< 1
1973	13	16	2
1974	10	23	2
1975	9	38	4
1976	13	26	3
1977	18	50	9

Purveyor: Rancho Los Amigos (#28)

Year	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)
1961	0	100	0
1962	0	100	0
1963	0	100	0
1964	0	100	0
1965	0	100	0
1966	0	100	0
1967	0	100	0
1968	1	100	1
1969	0	100	0
1970	0	100	0
1971	1	100	1
1972	1	100	1
1973	2	100	2
1974	7	100	7
1975	8	100	8
1976	8	100	8
1977	11	100	11

Purveyor: Rancho Santa Gertrudes Mutual Water Company (#29)

Year	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)
1961	0	100	0
1962	0	100	0
1963	0	100	0
1964	0	100	0
1965	0	100	0
1966	< 1	100	< 1
1967	< 1	100	< 1
1968	< 1	100	< 1
1969	< 1	100	< 1
1970	1	100	1
1971	1	100	1
1972	2	100	2
1973	2	100	2
1974	3	100	3
1975	3	100	3
1976	3	100	3
1977	6	100	6

APPENDIX N (cont.)

Purveyor: City of South Gate (#30)

Year	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)
1961	0	100	0
1962	0	100	0
1963	0	66	0
1964	0	55	0
1965	0	60	0
1966	0	69	0
1967	0	65	0
1968	0	64	0
1969	0	69	0
1970	5	70	2
1971	10	64	< 1
1972	15	67	< 1
1973	21	69	< 1
1974	26	71	< 1
1975	32	87	< 1
1976	37	70	1
1977	42	85	1

Purveyor: Tract No. 180 Water Company (#31)

Year	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)
1961	0	100	0
1962	0	100	0
1963	0	100	0
1964	0	100	0
1965	0	100	0
1966	0	100	0
1967	0	100	0
1968	0	100	0
1969	0	100	0
1970	0	100	0
1971	0	100	0
1972	0	100	0
1973	0	100	0
1974	0	100	0
1975	0	100	0
1976	0	100	0
1977	0	100	0

Purveyor: Tract No. 349 Mutual Water Company (#32)

Year	% Reclaimed Pumped (Pr)	% Ground-water in total supply (G)	% Reclaimed in total supply (Tr)
1961	0	100	0
1962	0	100	0
1963	0	100	0
1964	0	100	0
1965	0	100	0
1966	0	100	0
1967	0	100	0
1968	0	100	0
1969	0	100	0
1970	0	100	0
1971	0	100	0
1972	0	100	0
1973	0	100	0
1974	0	100	0
1975	0	100	0
1976	0	100	0
1977	0	100	0

O

EPIDEMIOLOGY PLOTS

FIGURE O-1
PROPORTIONATE MORTALITY RATIOS (PMRs) ADJUSTED FOR AGE AND SEX DISEASES OF HEART 1972-78

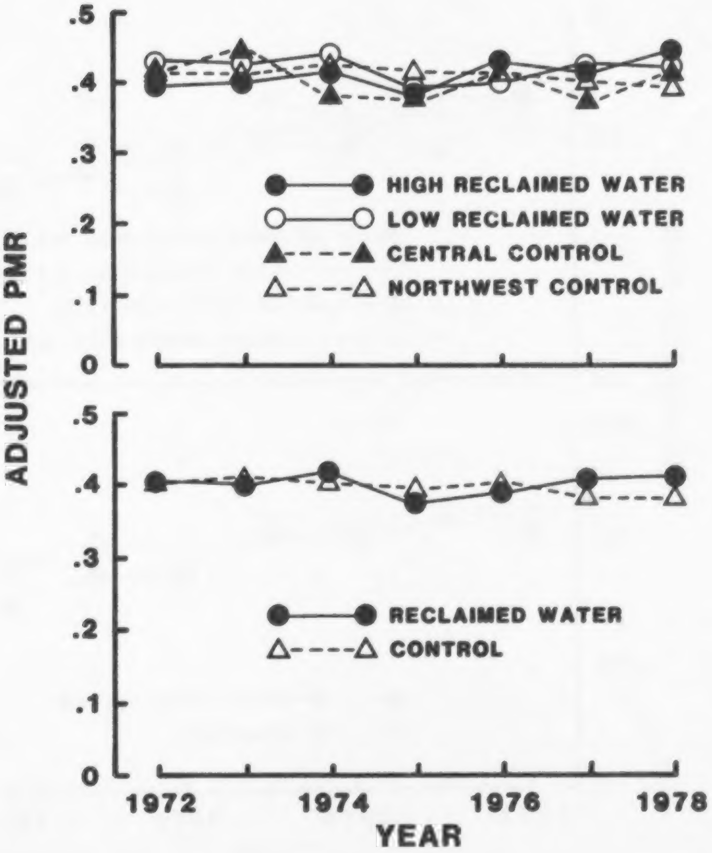


FIGURE O-2
PROPORTIONATE MORTALITY RATIOS (PMRs) ADJUSTED FOR AGE AND SEX CEREBROVASCULAR DISEASES 1972-78

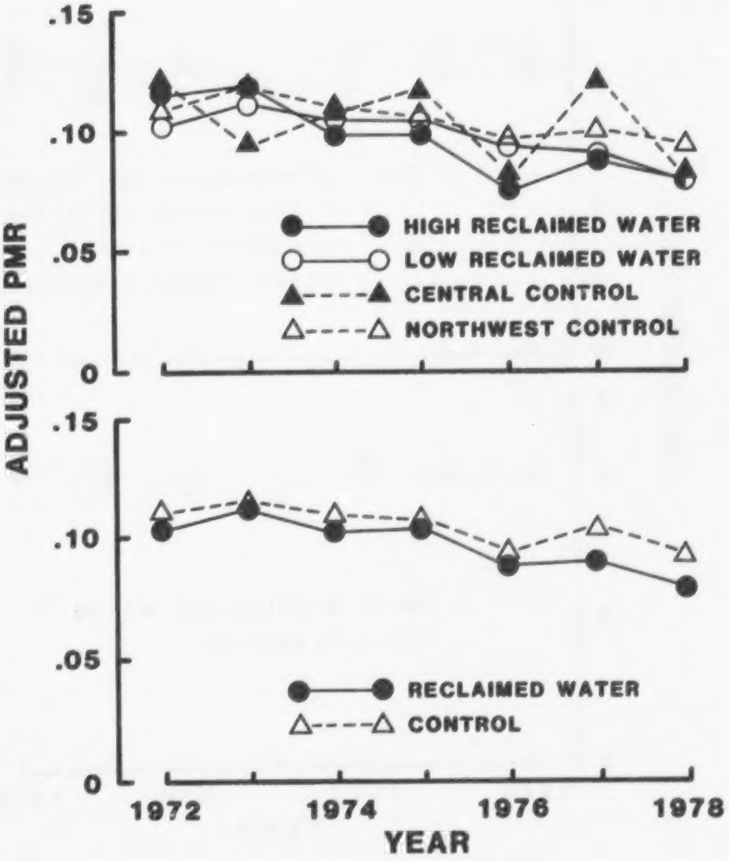


FIGURE O-3

PROPORTIONATE MORTALITY RATIOS
(PMRs)
ADJUSTED FOR AGE AND SEX
MALIGNANT NEOPLASMS 1972-78

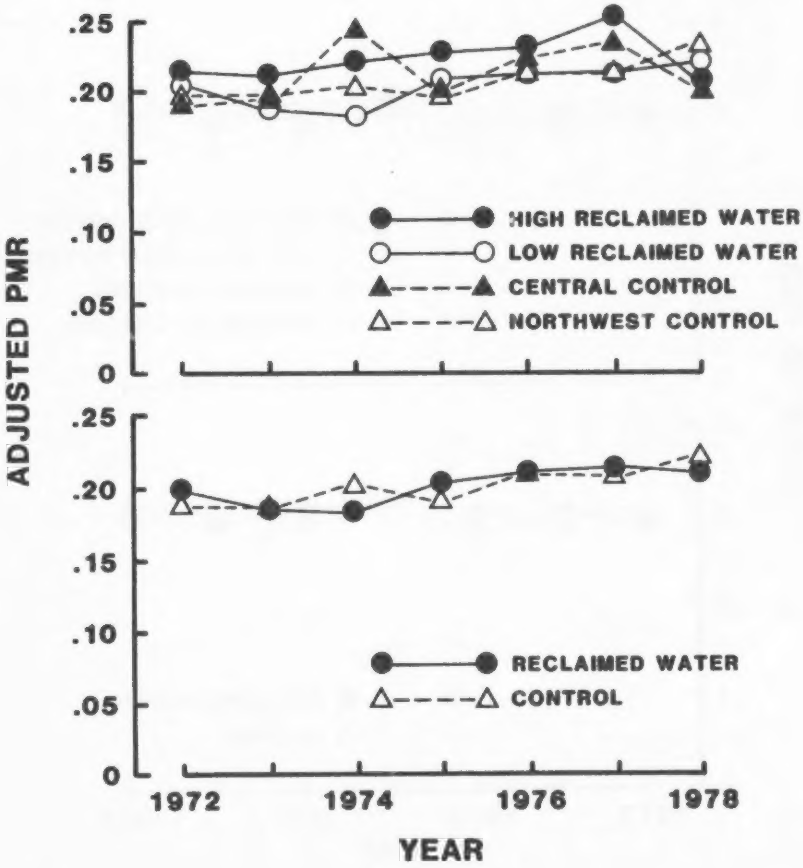


FIGURE O-4
PROPORTIONATE MORTALITY RATIOS (PMRs) ADJUSTED FOR AGE AND SEX ALL OTHER CAUSES OF DEATH 1972-78

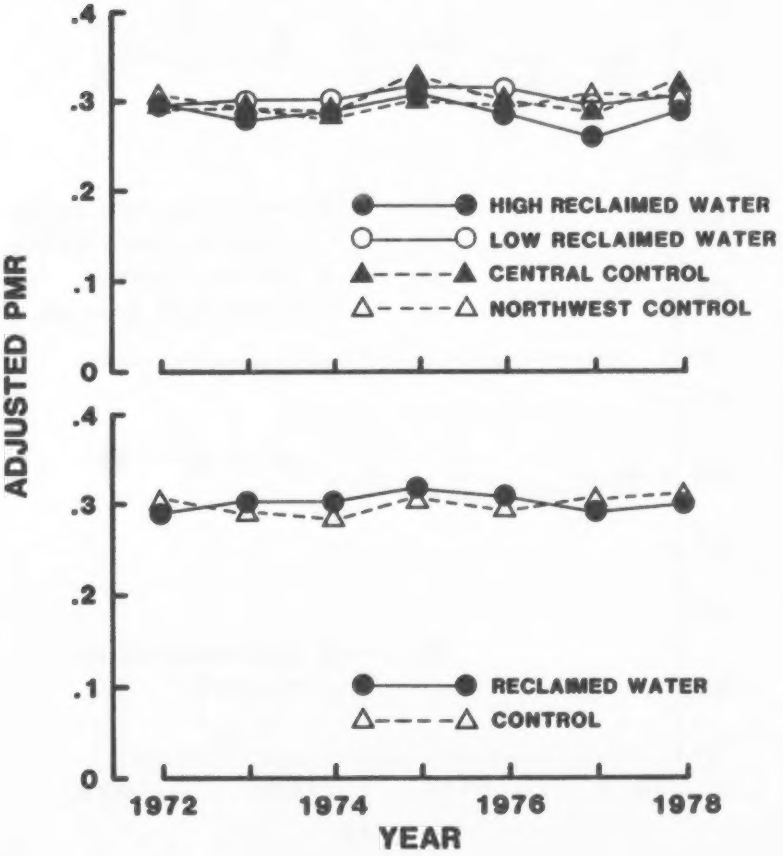


FIGURE O-5
STANDARDIZED PROPORTIONATE MORTALITY RATIOS (SPMRs) ADJUSTED FOR AGE AND SEX MALIGNANT NEOPLASM OF STOMACH 1972-78

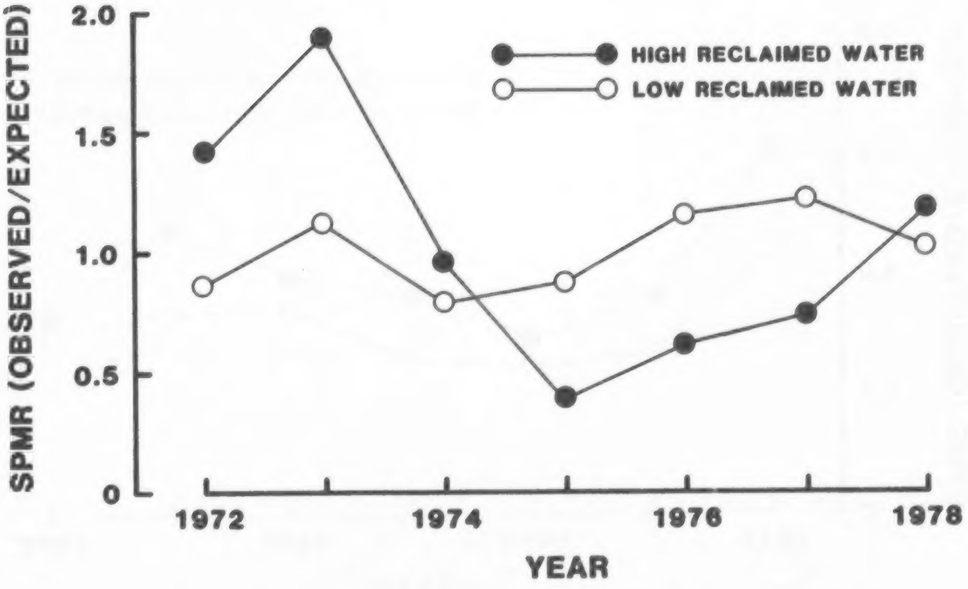


FIGURE O-6
STANDARDIZED PROPORTIONATE MORTALITY RATIOS (SPMRs)
ADJUSTED FOR AGE AND SEX
MALIGNANT NEOPLASM OF COLON 1972-78

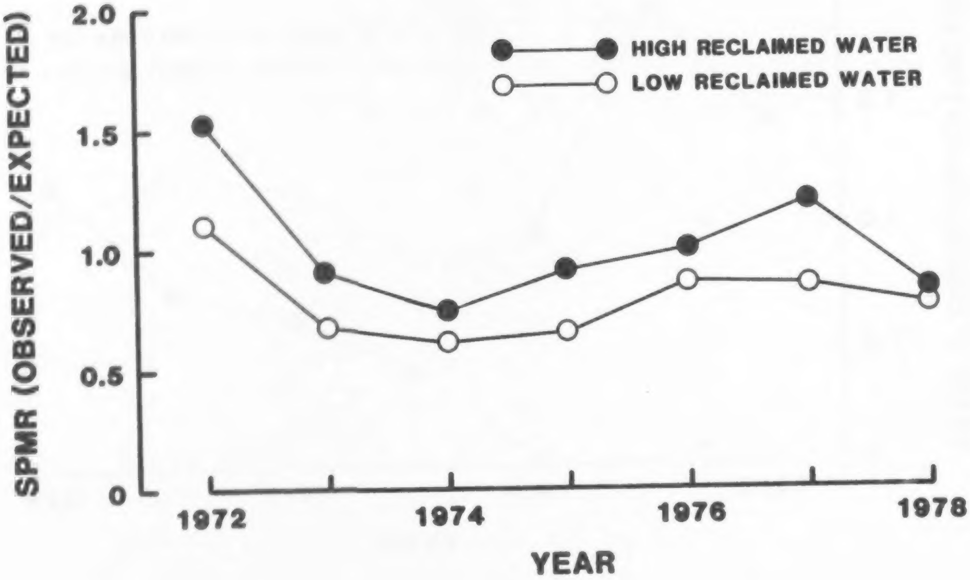


FIGURE O-7
STANDARDIZED PROPORTIONATE MORTALITY RATIOS (SPMRs) ADJUSTED FOR AGE AND SEX MALIGNANT NEOPLASM OF BLADDER 1972-78

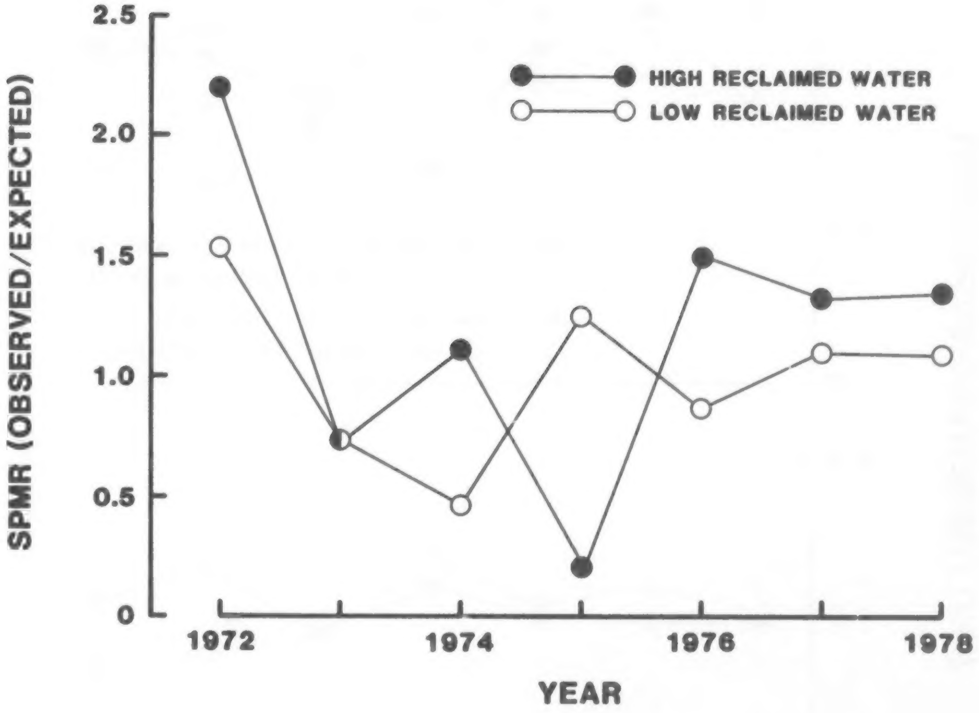


FIGURE O-8
STANDARDIZED PROPORTIONATE INCIDENCE RATIOS (SPIRs) ADJUSTED FOR AGE, RACE AND SEX MALIGNANT NEOPLASM OF STOMACH 1972-78

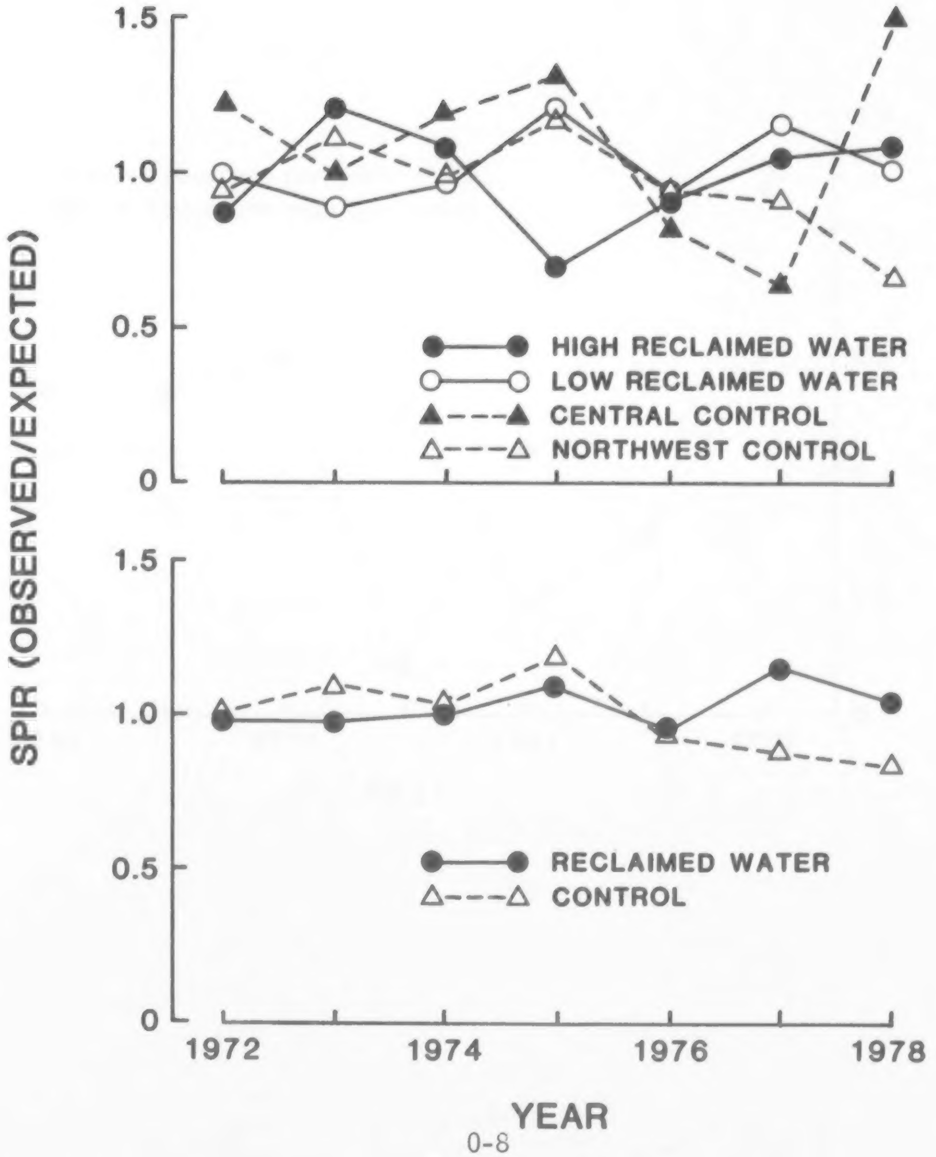


FIGURE O-9

STANDARDIZED PROPORTIONATE INCIDENCE RATIOS (SPIRs)

ADJUSTED FOR AGE, RACE AND SEX

MALIGNANT NEOPLASM OF COLON

1972-78

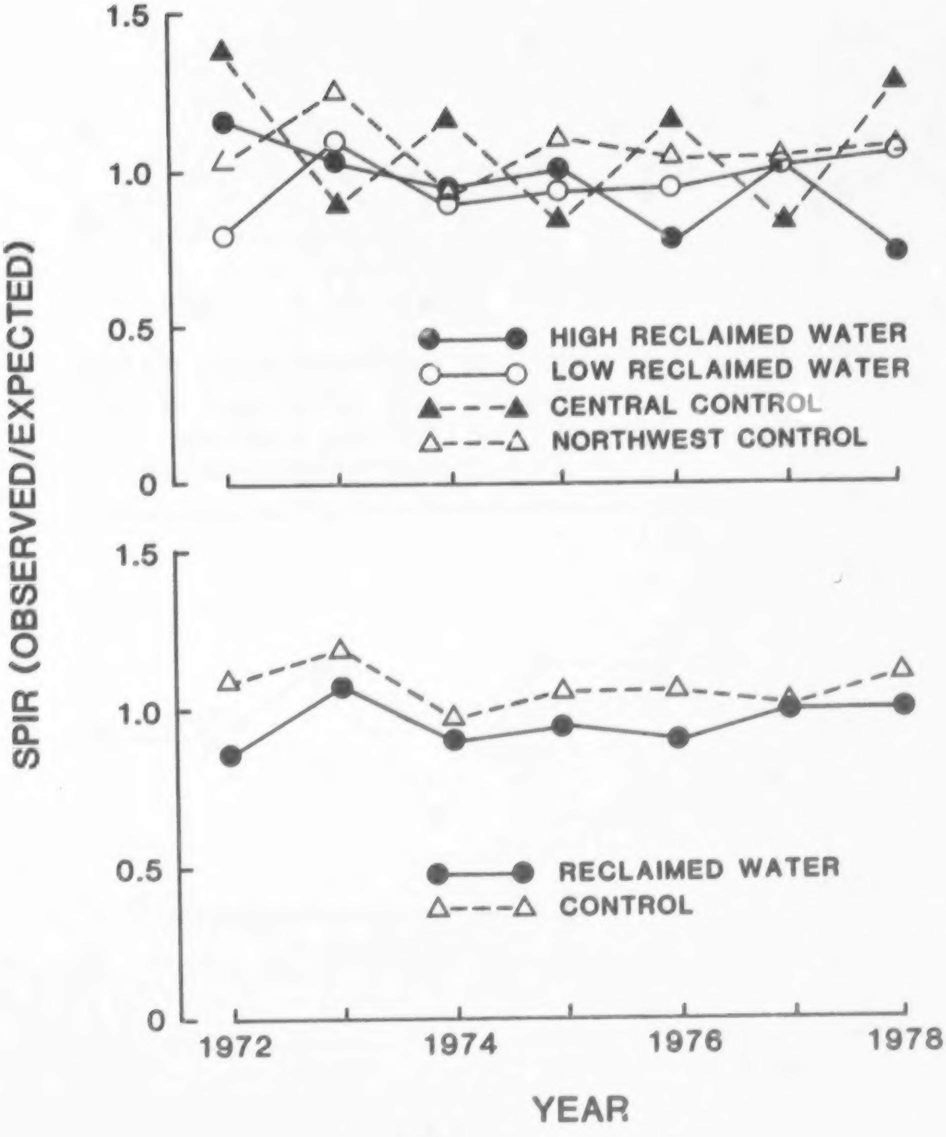


FIGURE O-10

STANDARDIZED PROPORTIONATE INCIDENCE RATIOS (SPIRs) ADJUSTED FOR AGE, RACE AND SEX MALIGNANT NEOPLASM OF RECTUM 1972-78

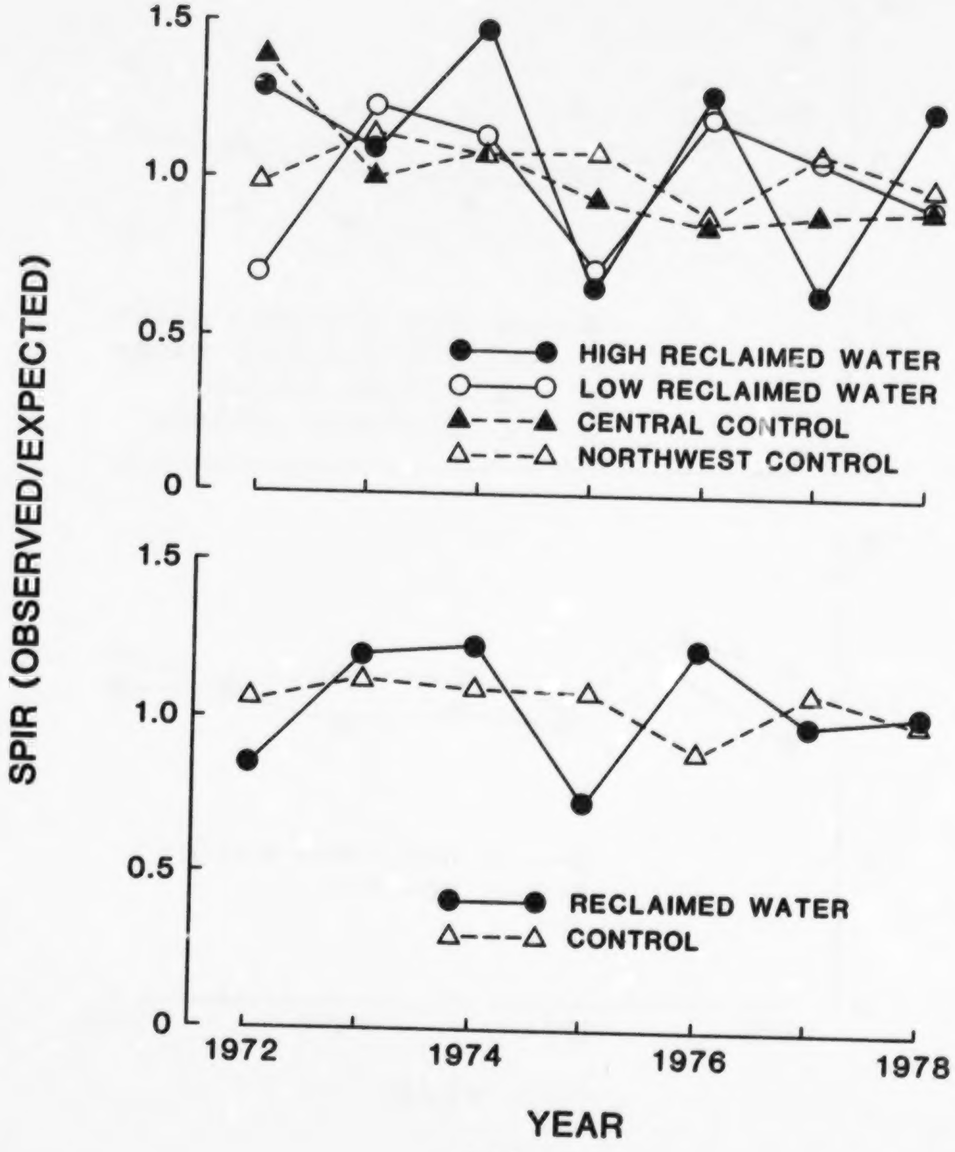


FIGURE O-11

STANDARDIZED PROPORTIONATE INCIDENCE RATIOS (SPIRs) ADJUSTED FOR AGE, RACE AND SEX MALIGNANT NEOPLASM OF BLADDER 1972-78

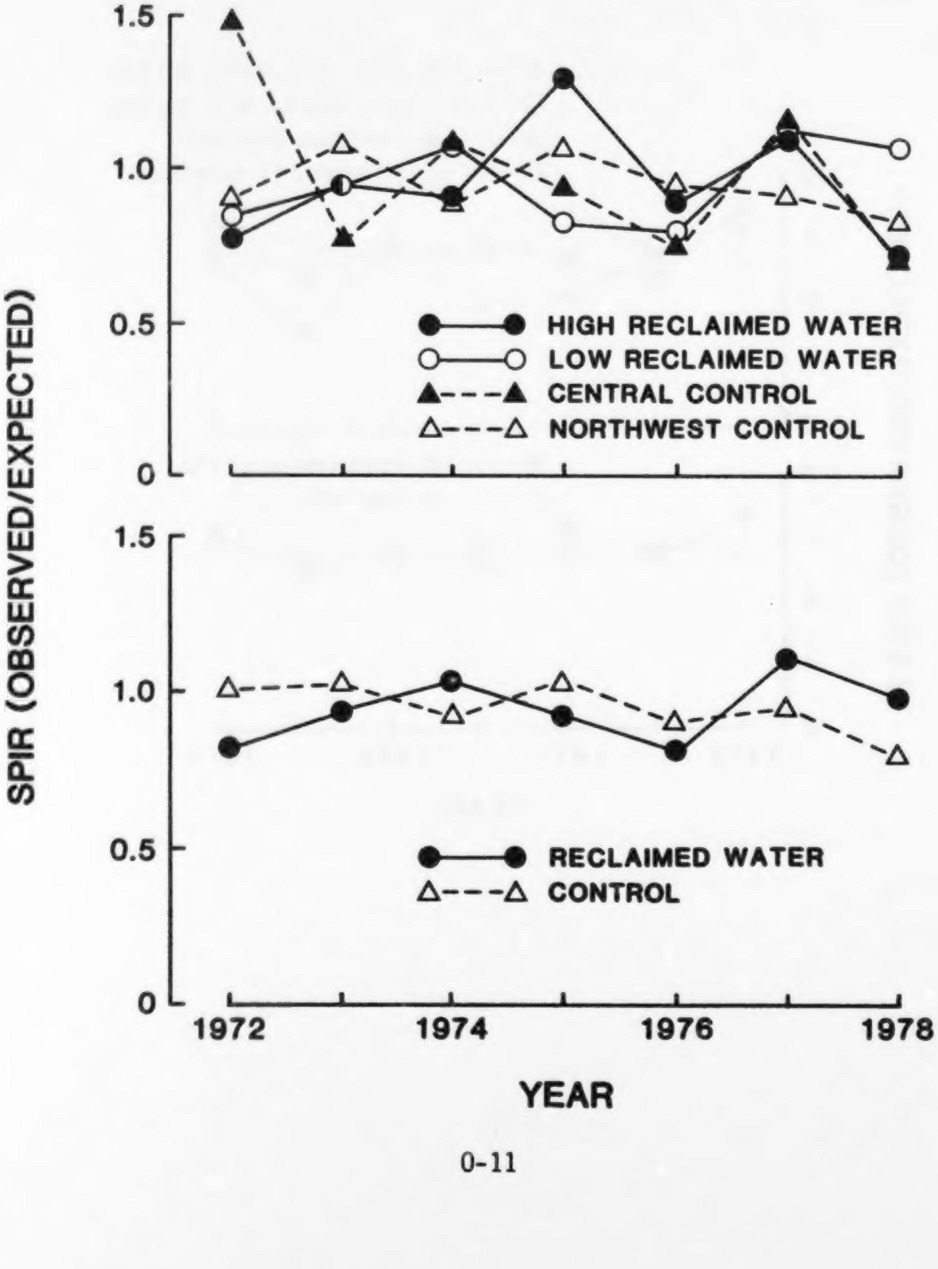


FIGURE O-12
STANDARDIZED LOW BIRTH WEIGHT RATIOS (SLBWRs) ADJUSTED FOR MATERNAL AGE 1972-78

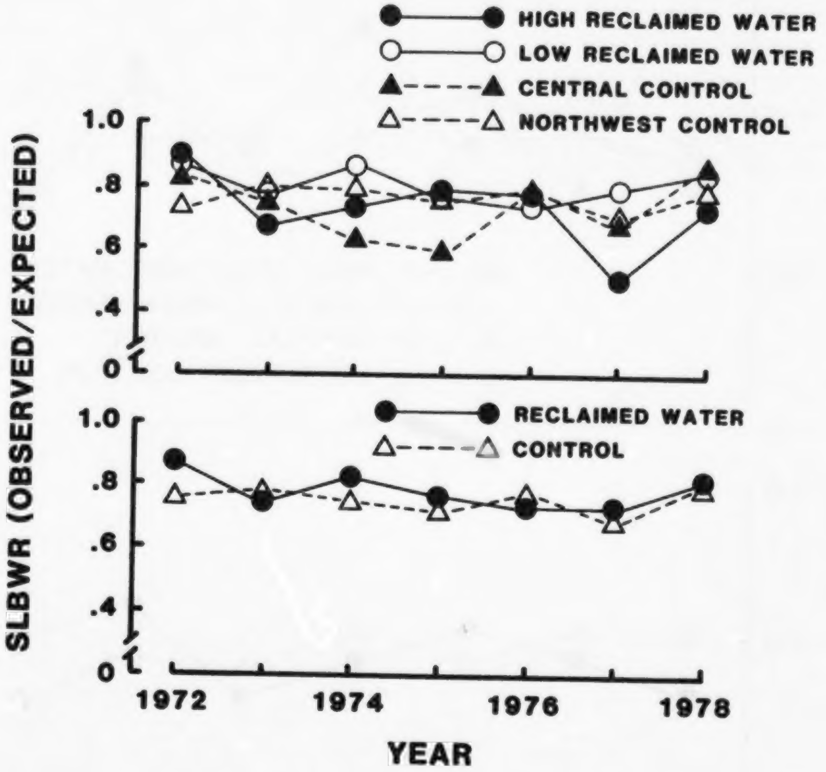


FIGURE O-13
STANDARDIZED VERY LOW BIRTH WEIGHT RATIOS (SVLBWRs) ADJUSTED FOR MATERNAL AGE 1972-78

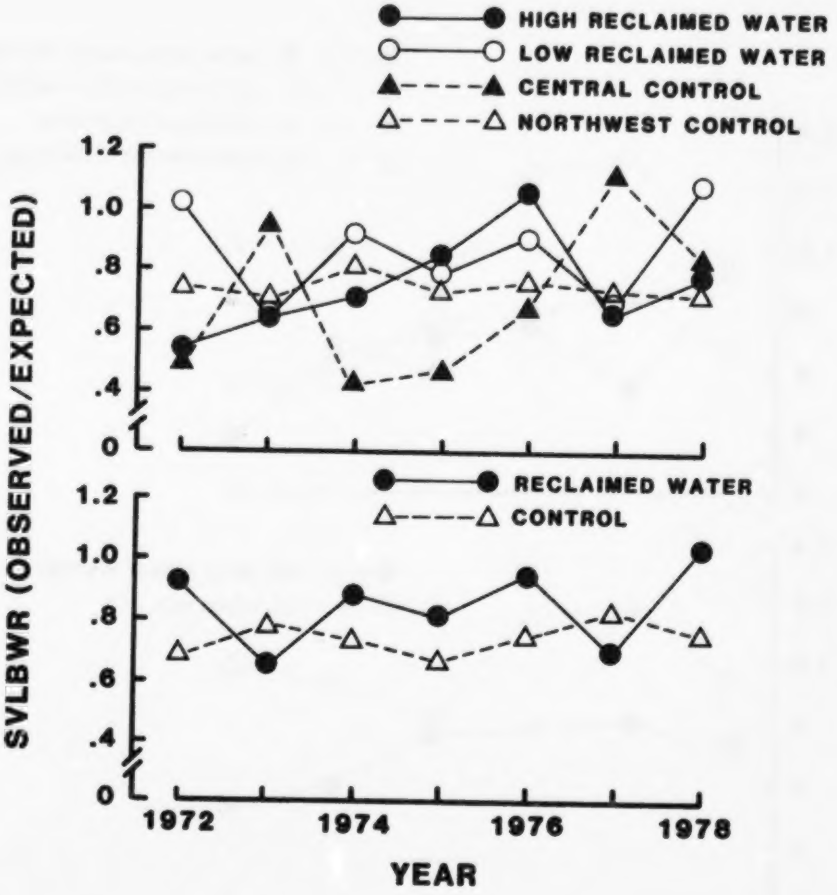


FIGURE O-14
STANDARDIZED CONGENITAL MALFORMATION RATIOS (SCMRs)
ADJUSTED FOR MATERNAL AGE AND INFANT BIRTH WEIGHT
1972-77

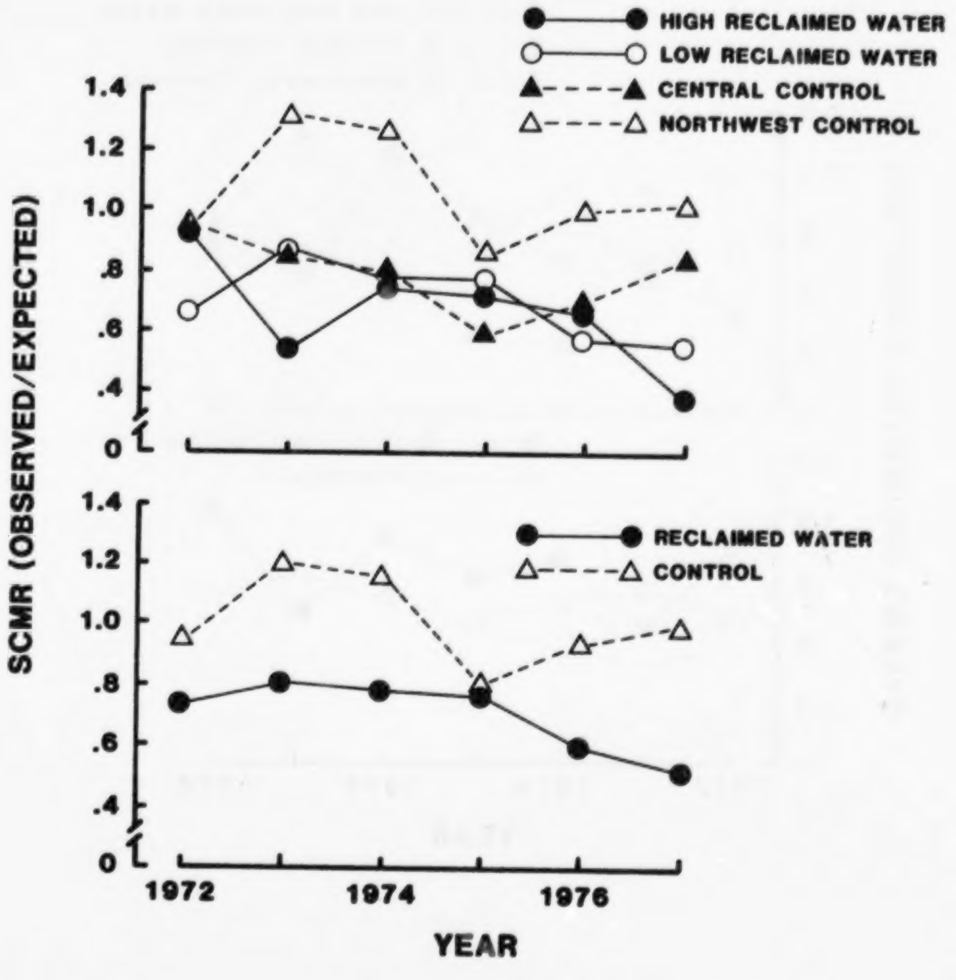


FIGURE O-15

STANDARDIZED INFANT MORTALITY RATIOS (SIMRs) ADJUSTED FOR MATERNAL AGE AND INFANT BIRTH WEIGHT 1972-78

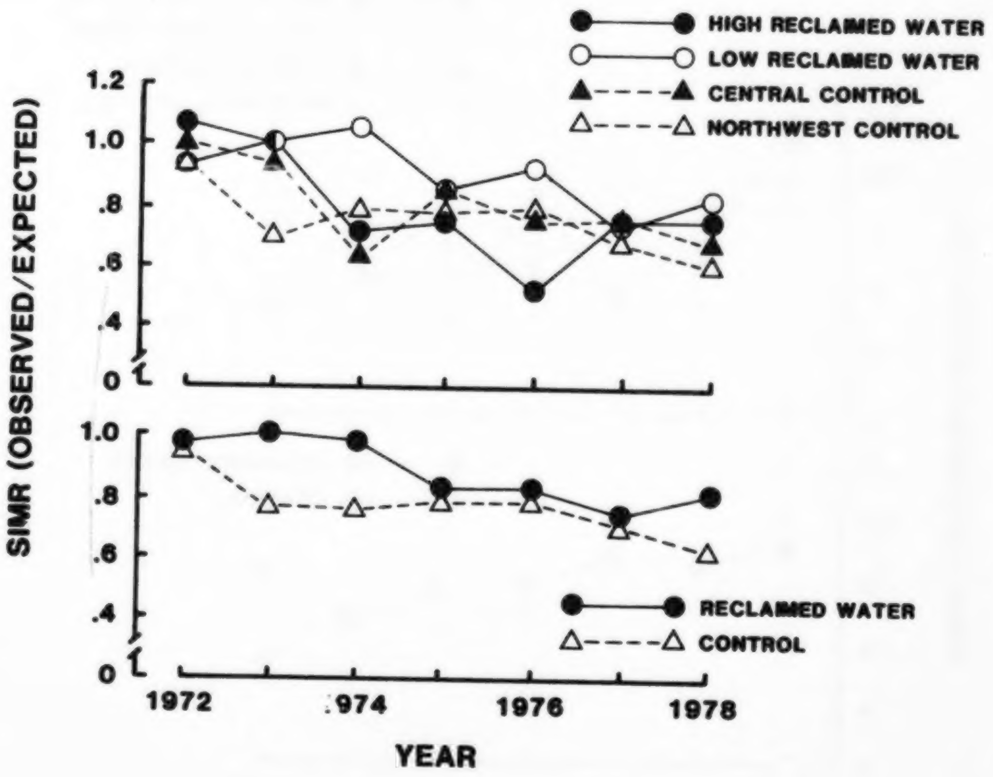


FIGURE O-16
STANDARDIZED NEONATAL MORTALITY RATIOS (SNMRs) ADJUSTED FOR MATERNAL AGE AND INFANT BIRTH WEIGHT 1972-78

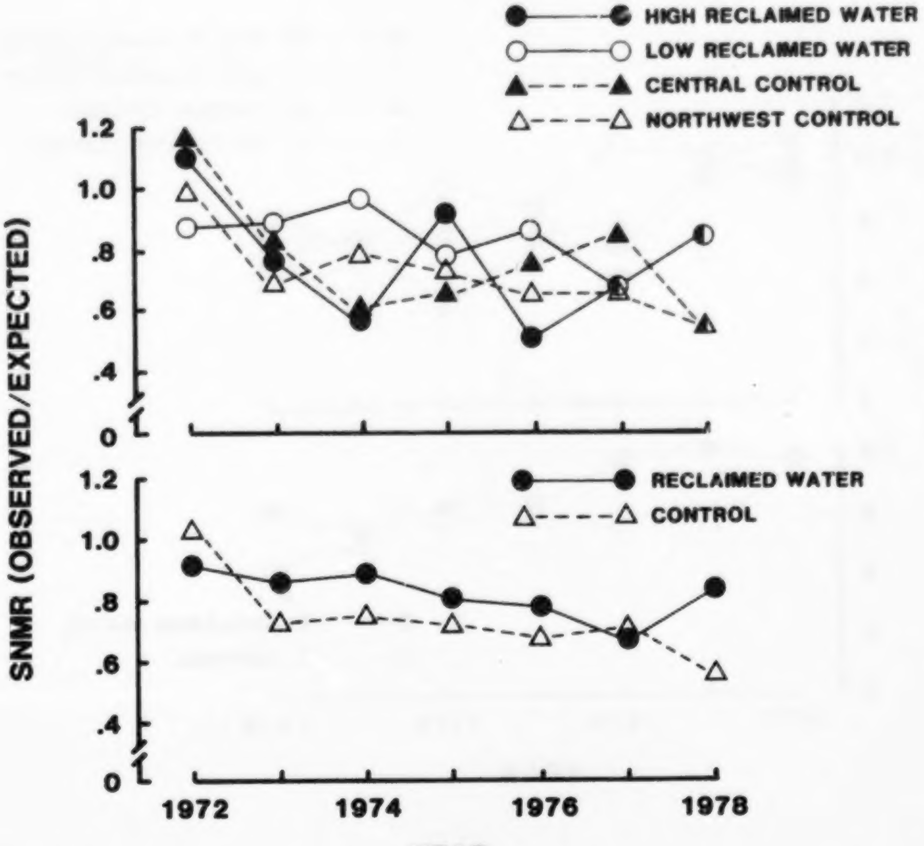


FIGURE O-17

MORTALITY RATES BY AGE AND STUDY AREA DEATH DUE TO ALL CAUSES 1979-80

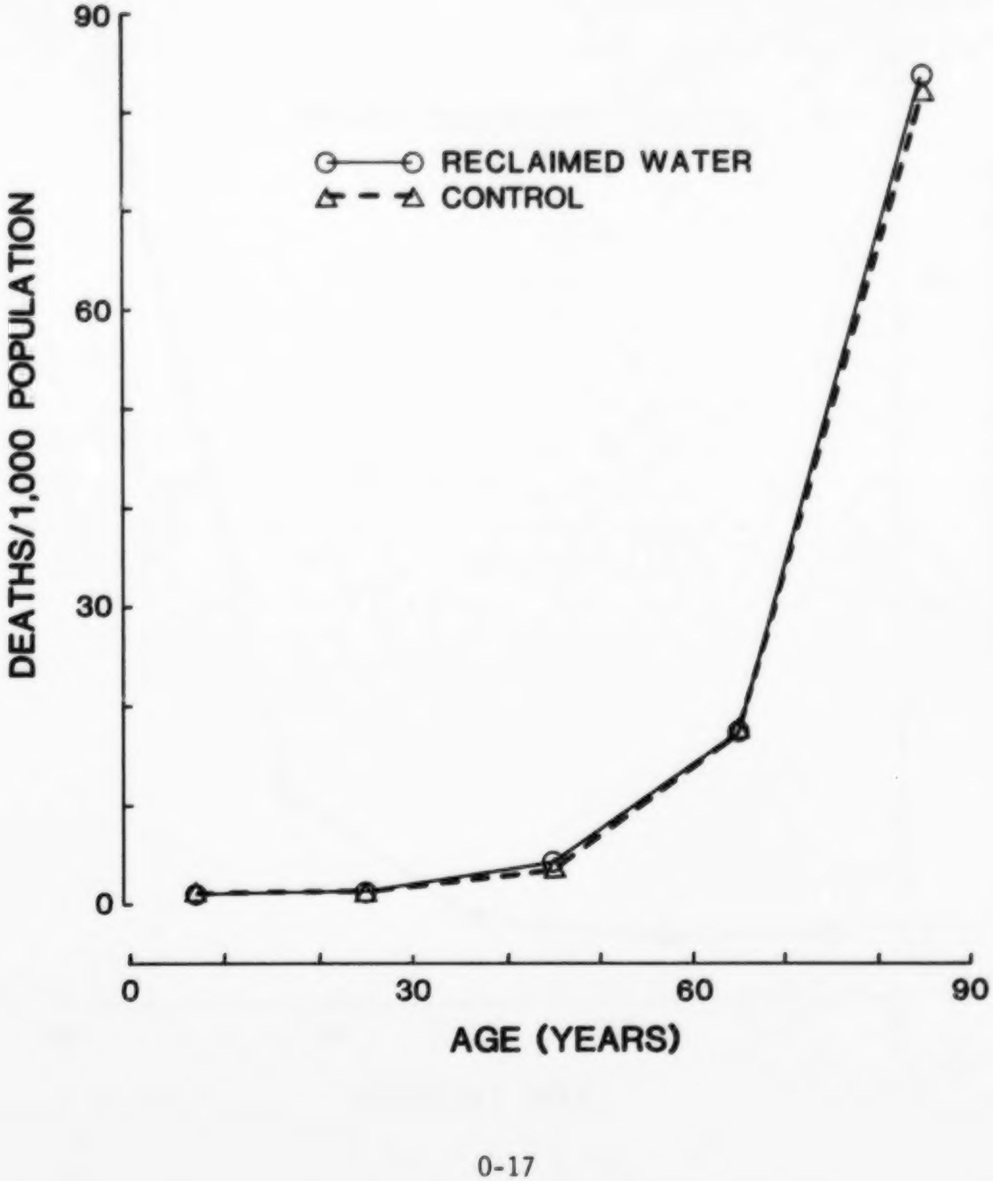


FIGURE O-18
MORTALITY RATES BY AGE AND STUDY AREA
DISEASES OF THE HEART 1979-80

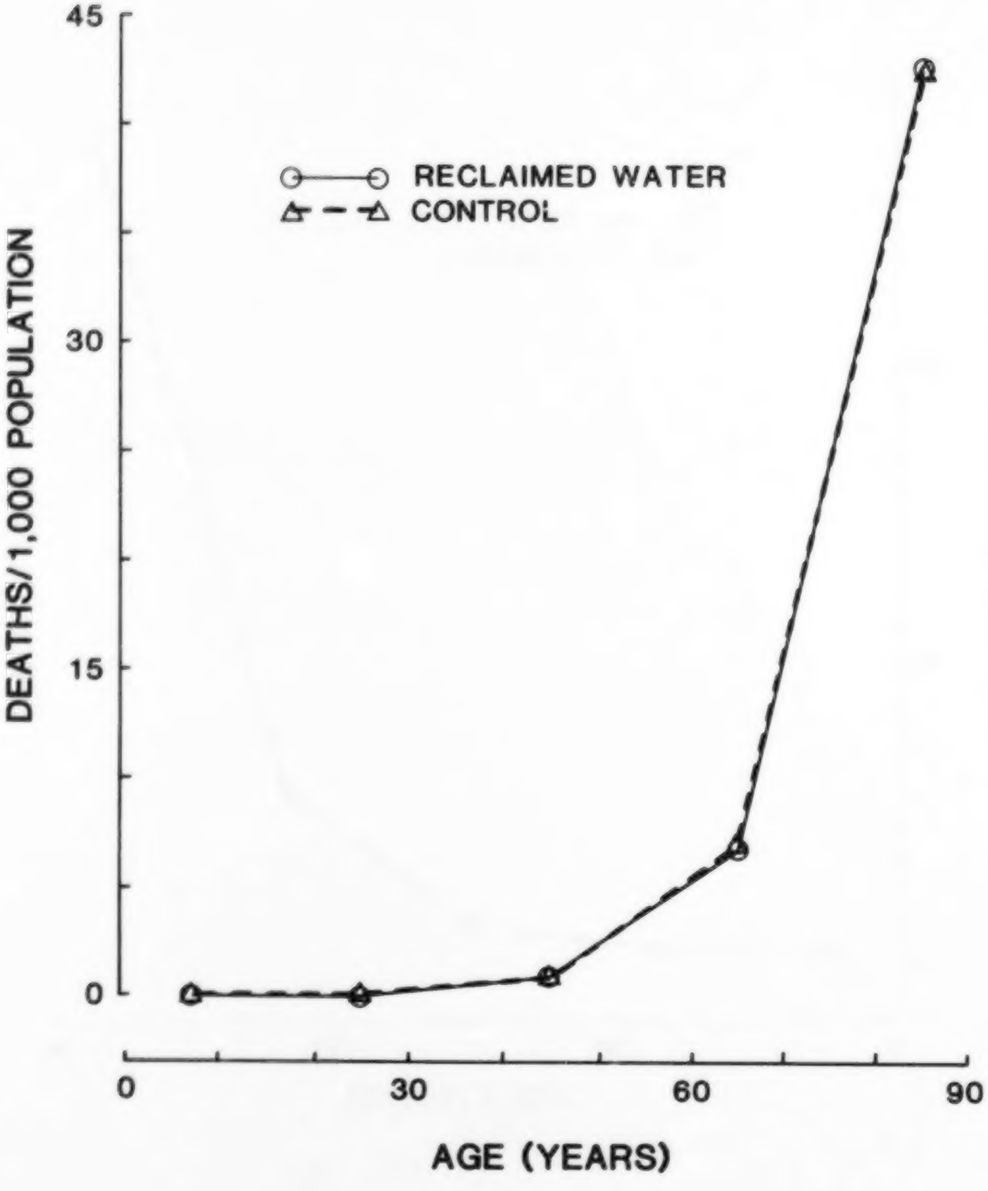


FIGURE O-19

MORTALITY RATES BY AGE AND STUDY AREA CEREBROVASCULAR DISEASE (STROKE) 1979-80

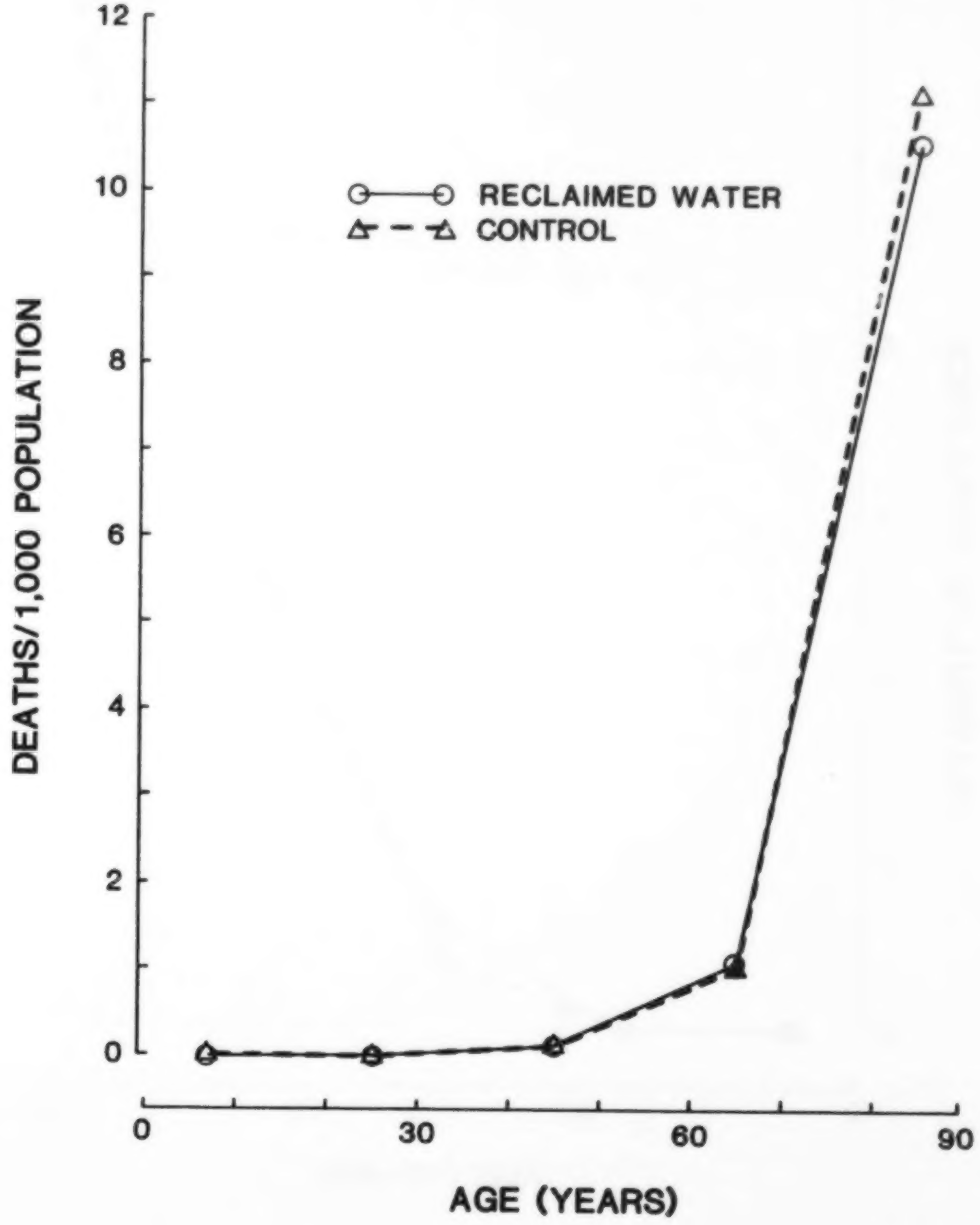


FIGURE O-20
MORTALITY RATES BY AGE AND STUDY AREA ALL MALIGNANT NEOPLASMS (CANCER) 1979-80

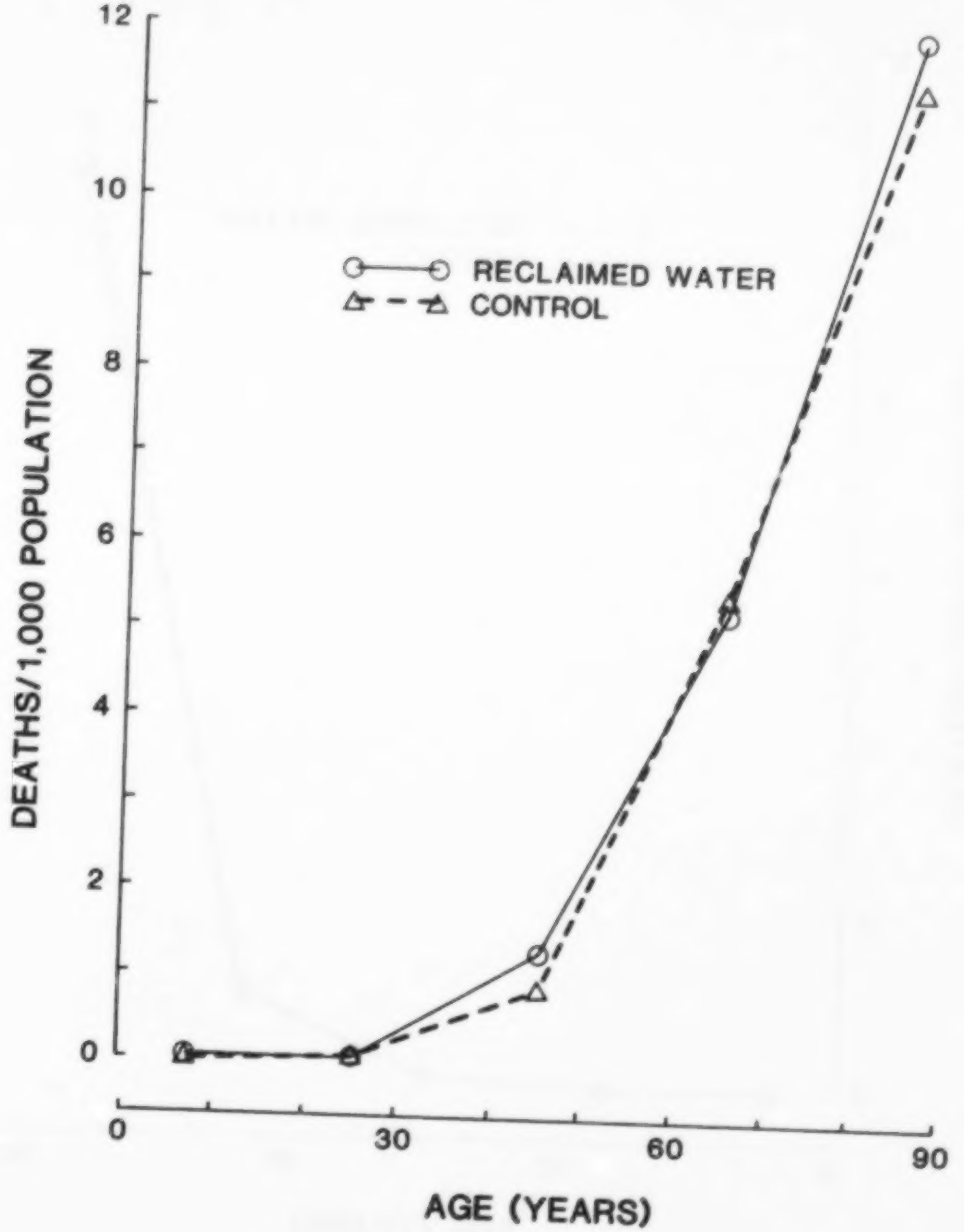


FIGURE O-21
MORTALITY RATES BY AGE AND STUDY AREA MALIGNANT NEOPLASM OF THE STOMACH 1979-80

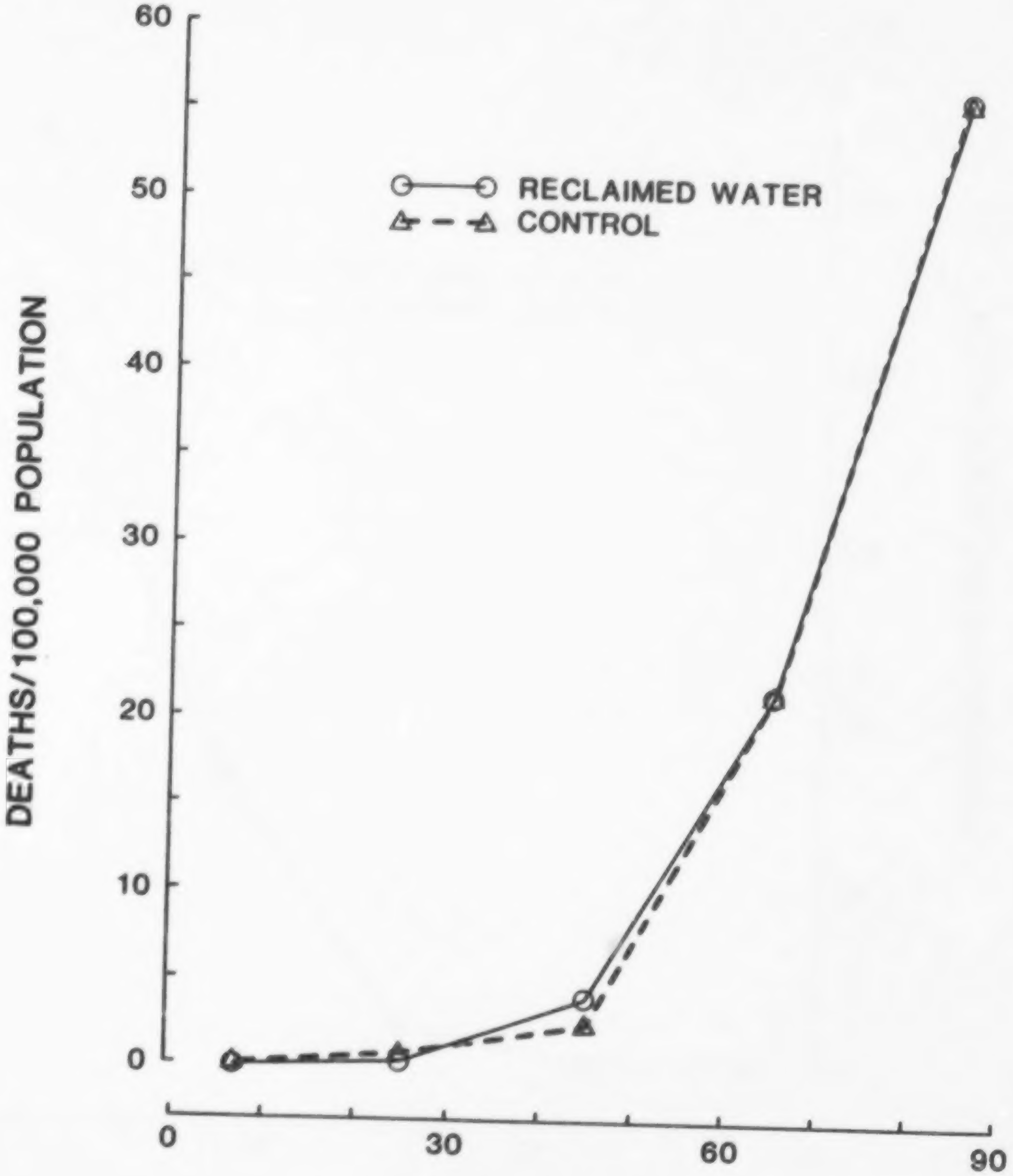


FIGURE O-22
MORTALITY RATES BY AGE AND STUDY AREA
MALIGNANT NEOPLASM OF THE COLON 1979-80

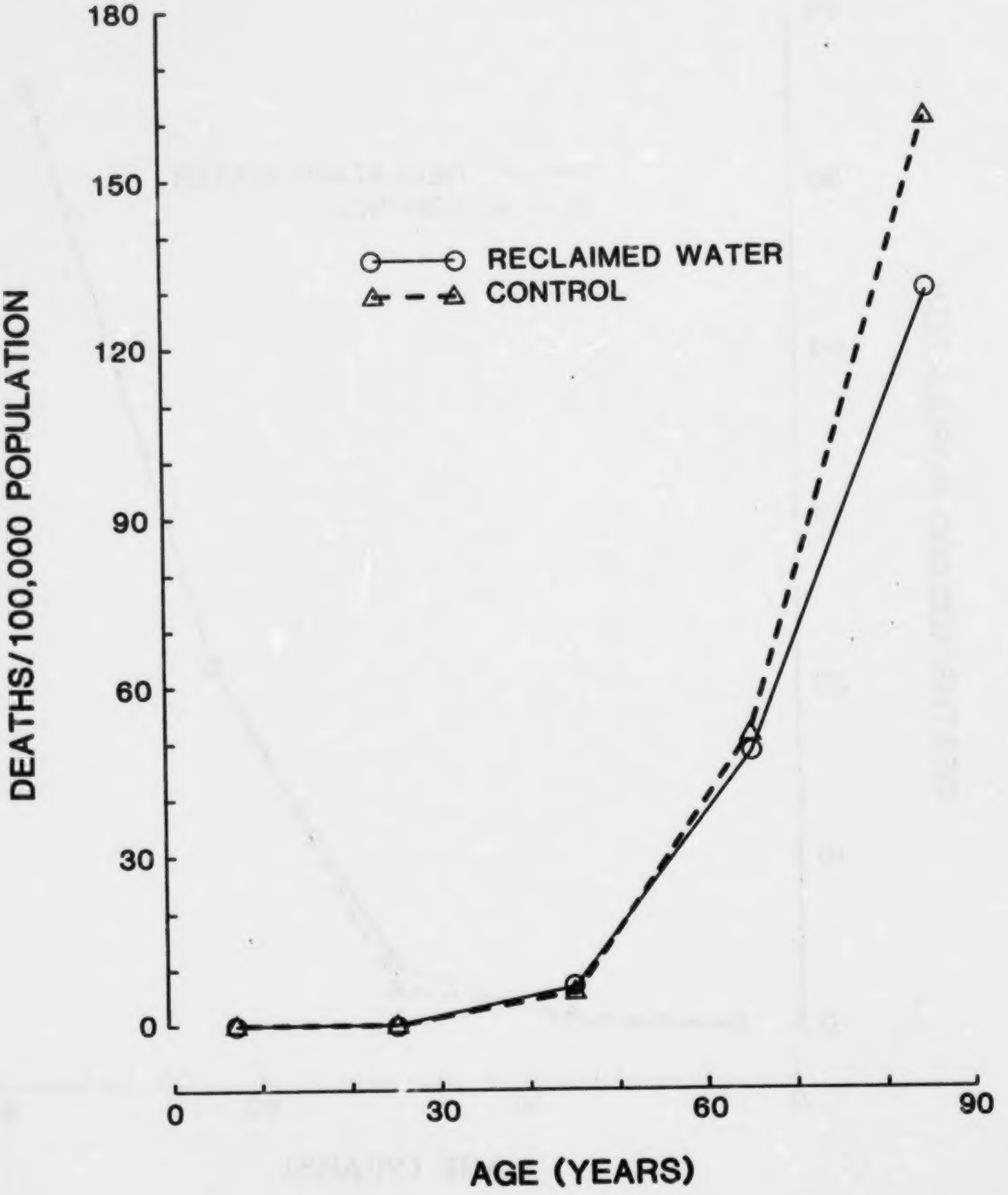


FIGURE O-23
MORTALITY RATES BY AGE AND STUDY AREA
MALIGNANT NEOPLASM OF THE RECTUM 1979-80

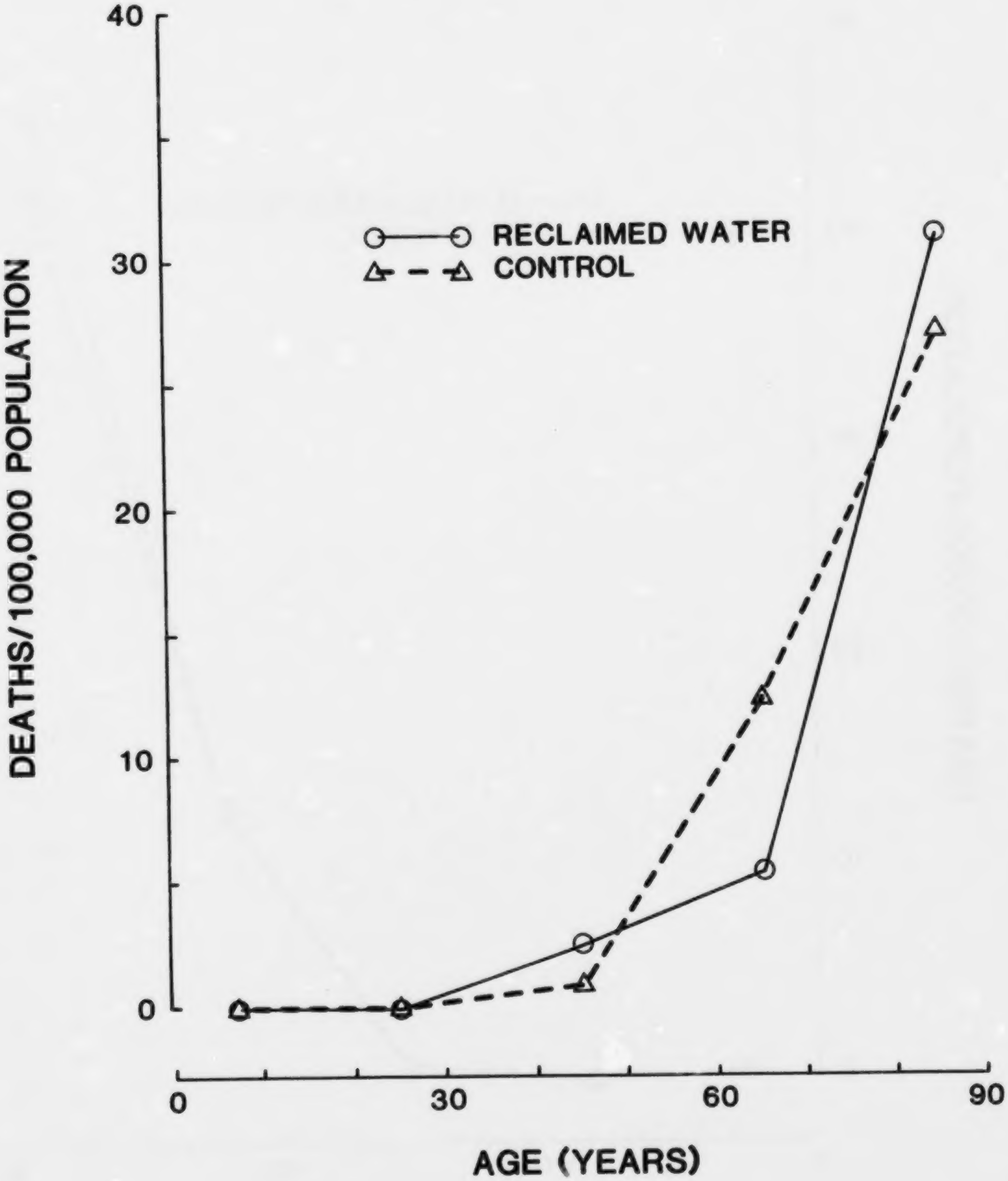


FIGURE O-24
MORTALITY RATES BY AGE AND STUDY AREA
MALIGNANT NEOPLASM OF THE BLADDER 1979-80

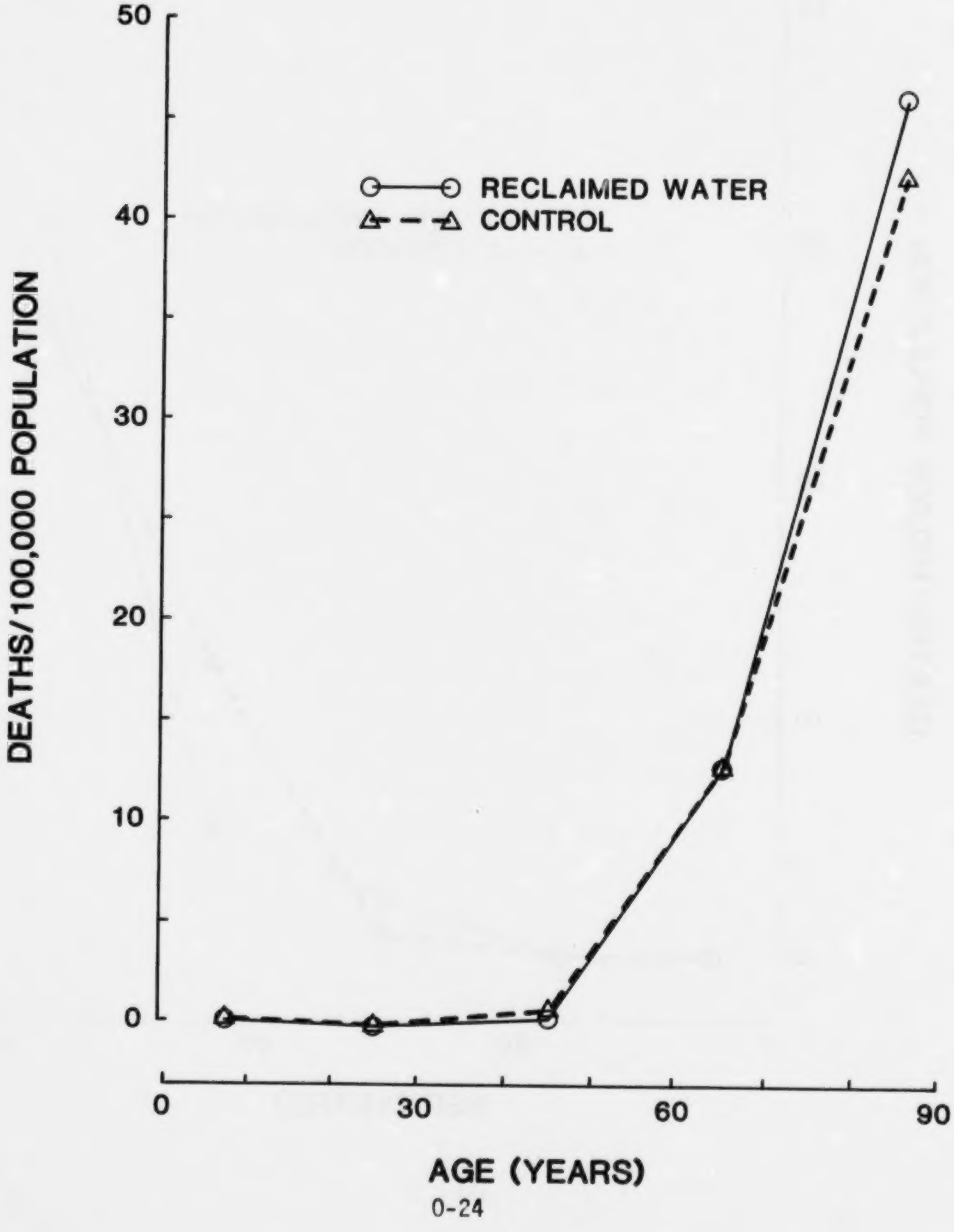


FIGURE O-25
MORTALITY RATES BY AGE AND STUDY AREA
DEATH DUE TO ALL CAUSES 1979-80

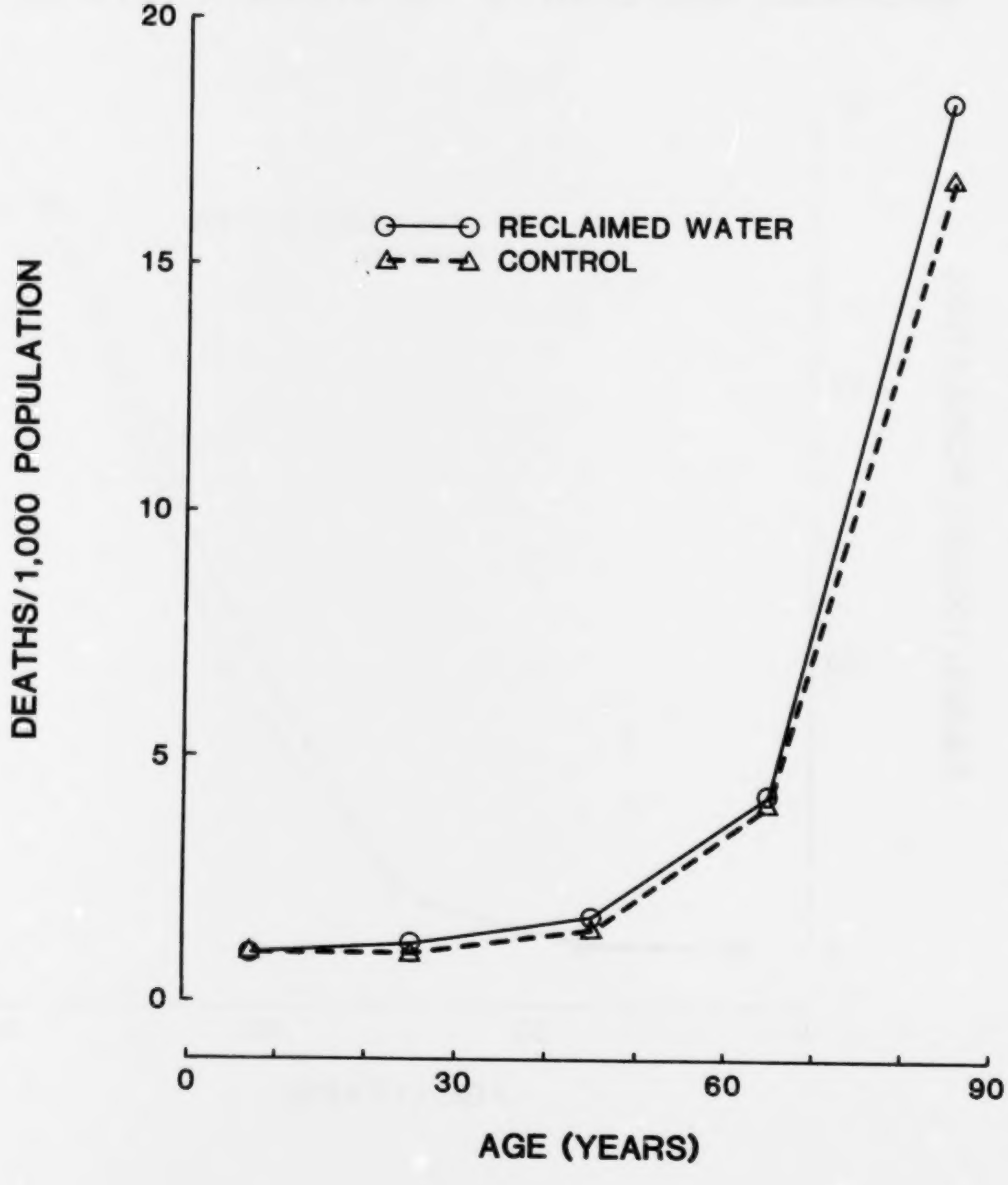


FIGURE O-26
INCIDENCE RATES BY AGE AND STUDY AREA MALIGNANT NEOPLASM OF THE STOMACH 1979-80

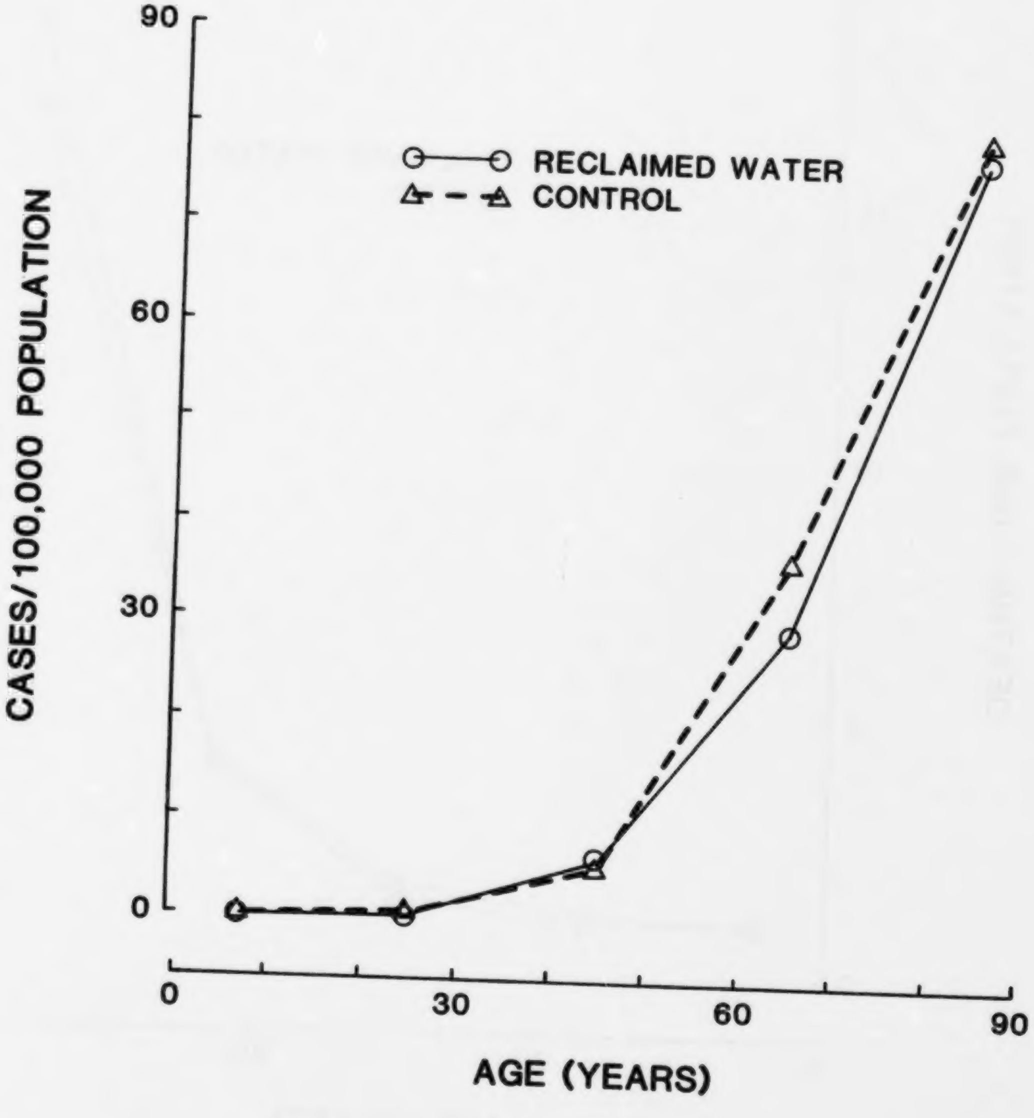


FIGURE O-27
INCIDENCE RATES BY AGE AND STUDY AREA MALIGNANT NEOPLASM OF THE COLON 1979-80

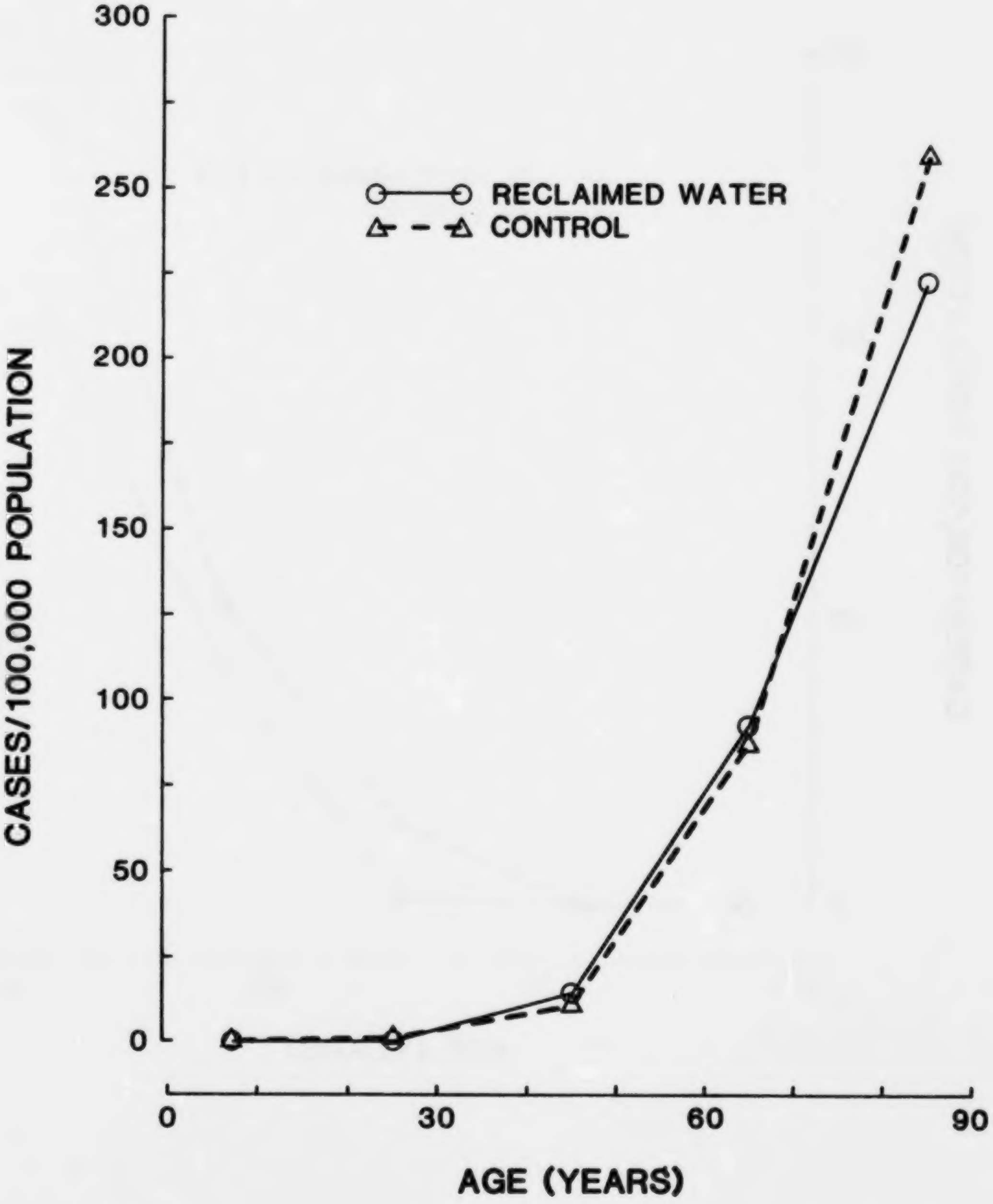


FIGURE O-28

INCIDENCE RATES BY AGE AND STUDY AREA MALIGNANT NEOPLASM OF THE RECTUM 1979-80

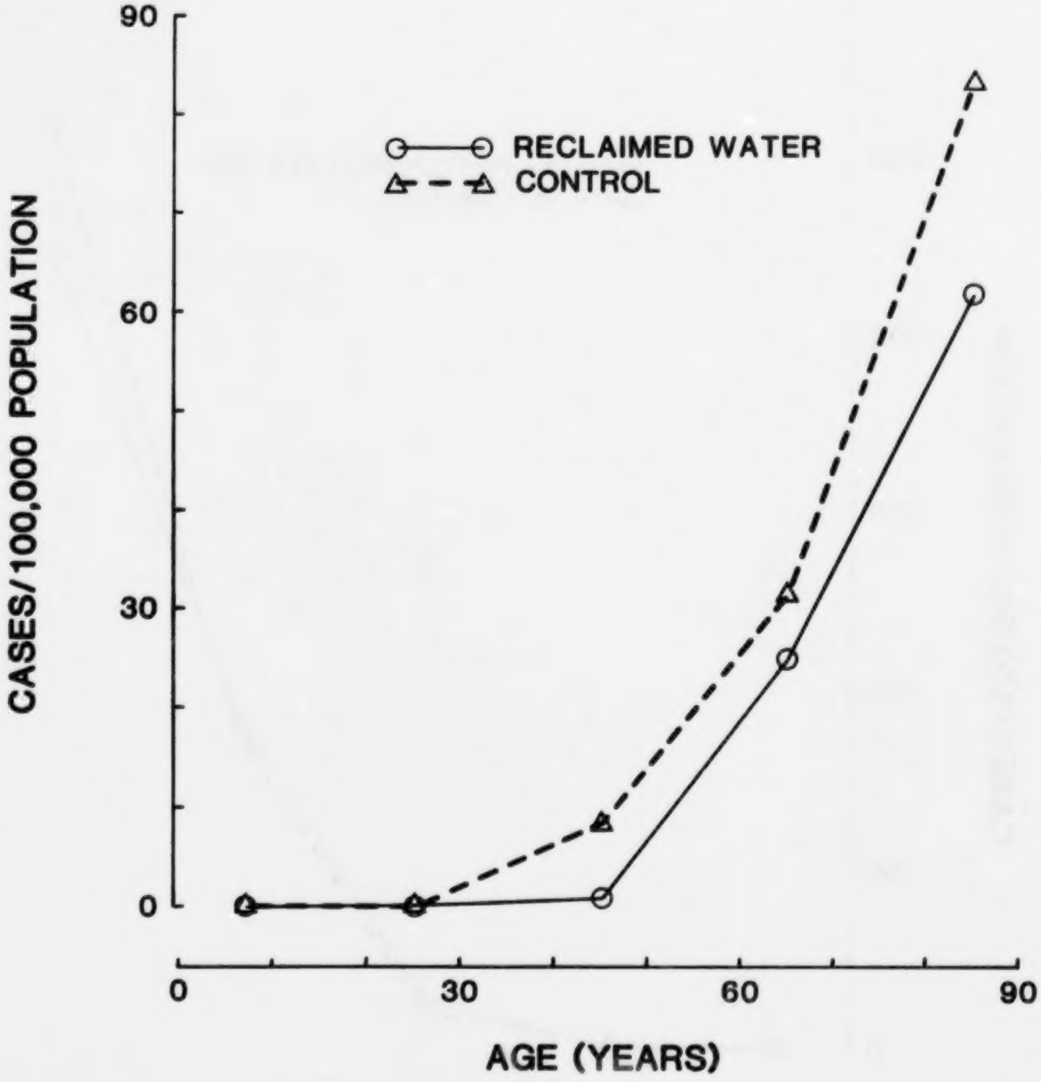


FIGURE O-29
INCIDENCE RATES BY AGE AND STUDY AREA
MALIGNANT NEOPLASM OF THE BLADDER 1979-80

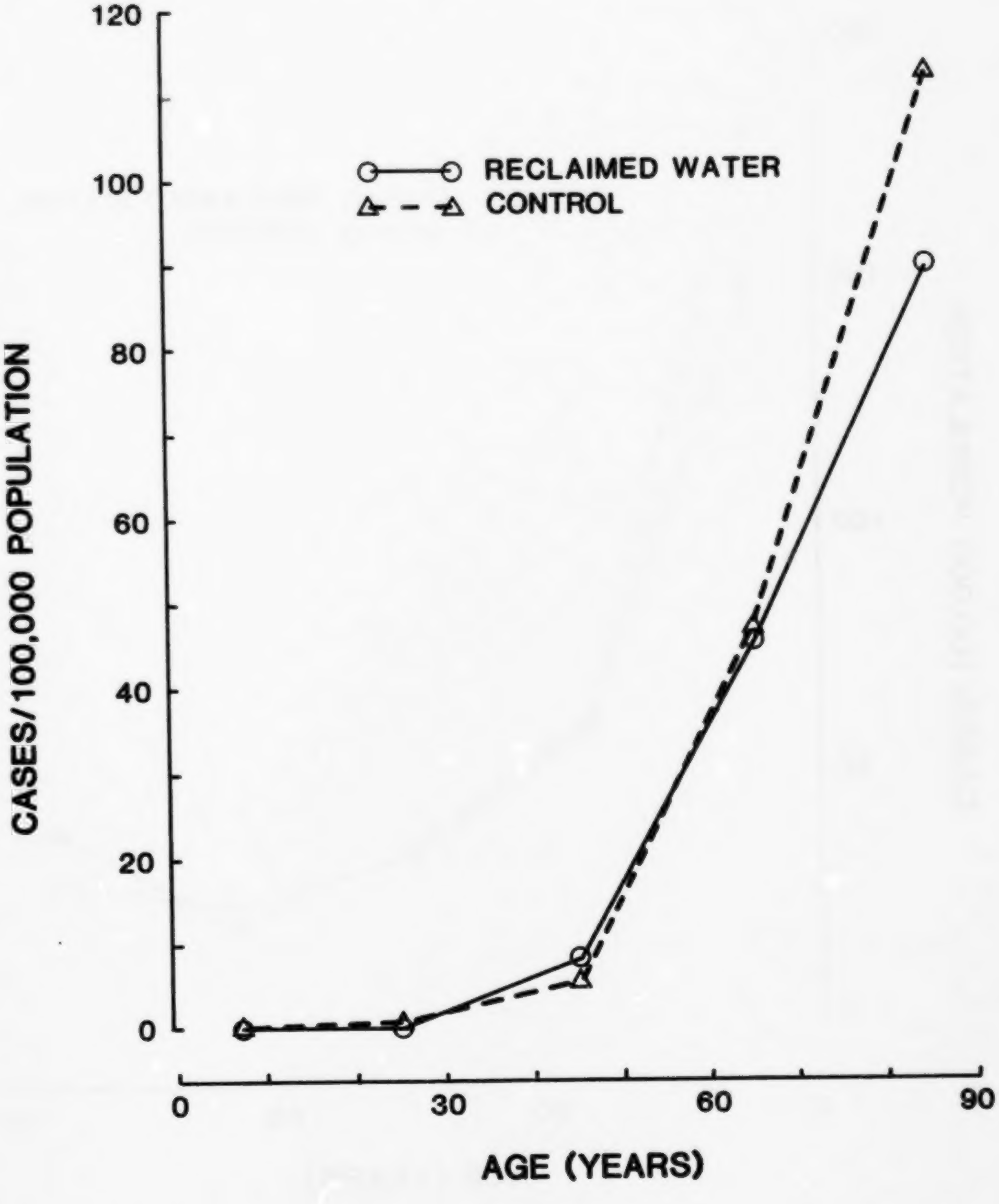


FIGURE 0-30
INCIDENCE RATES BY AGE AND STUDY AREA POTENTIAL WATERBORNE DISEASES 1979-80

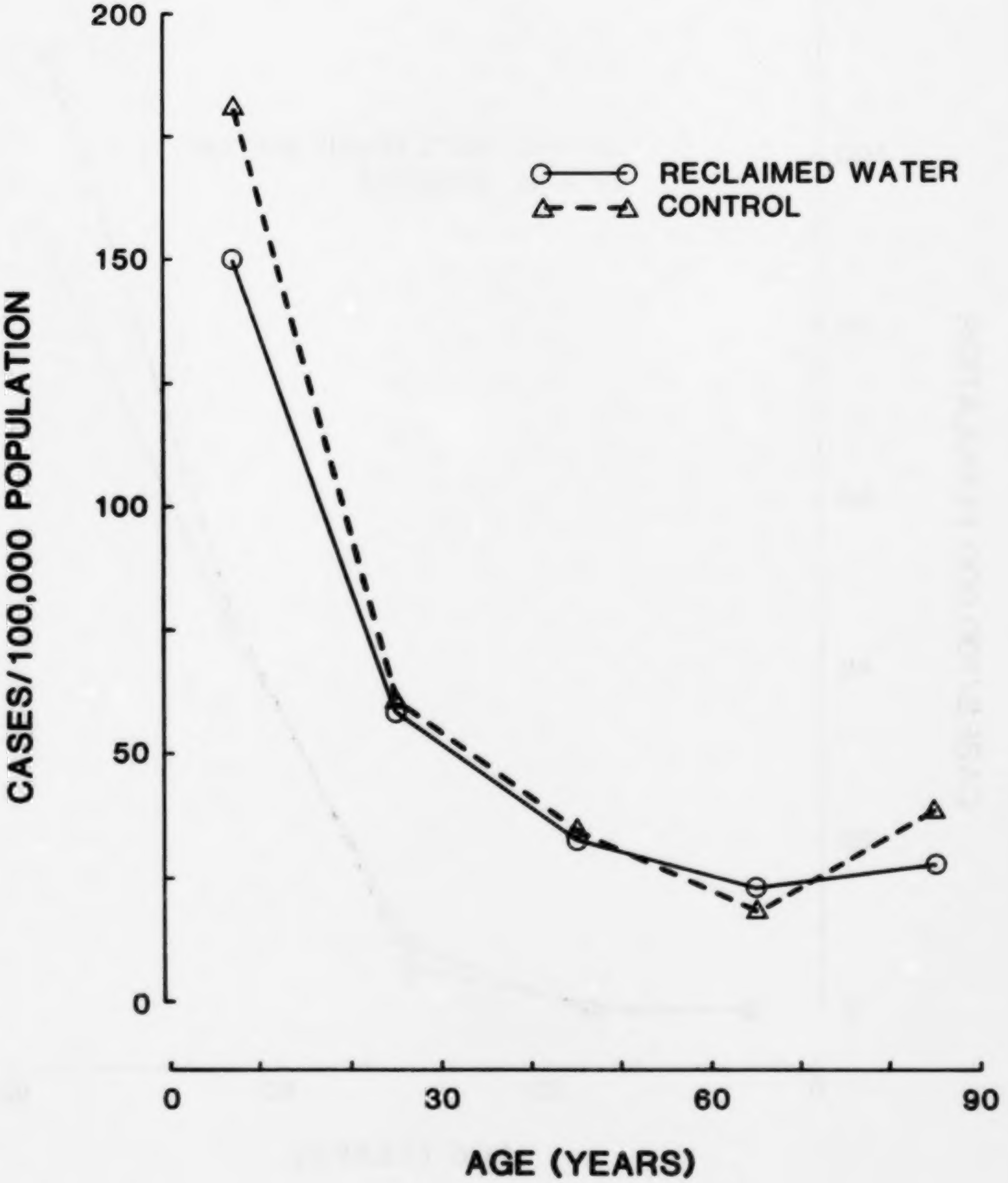


FIGURE O-31

INCIDENCE RATES BY AGE AND STUDY AREA

HEPATITIS A 1979-80

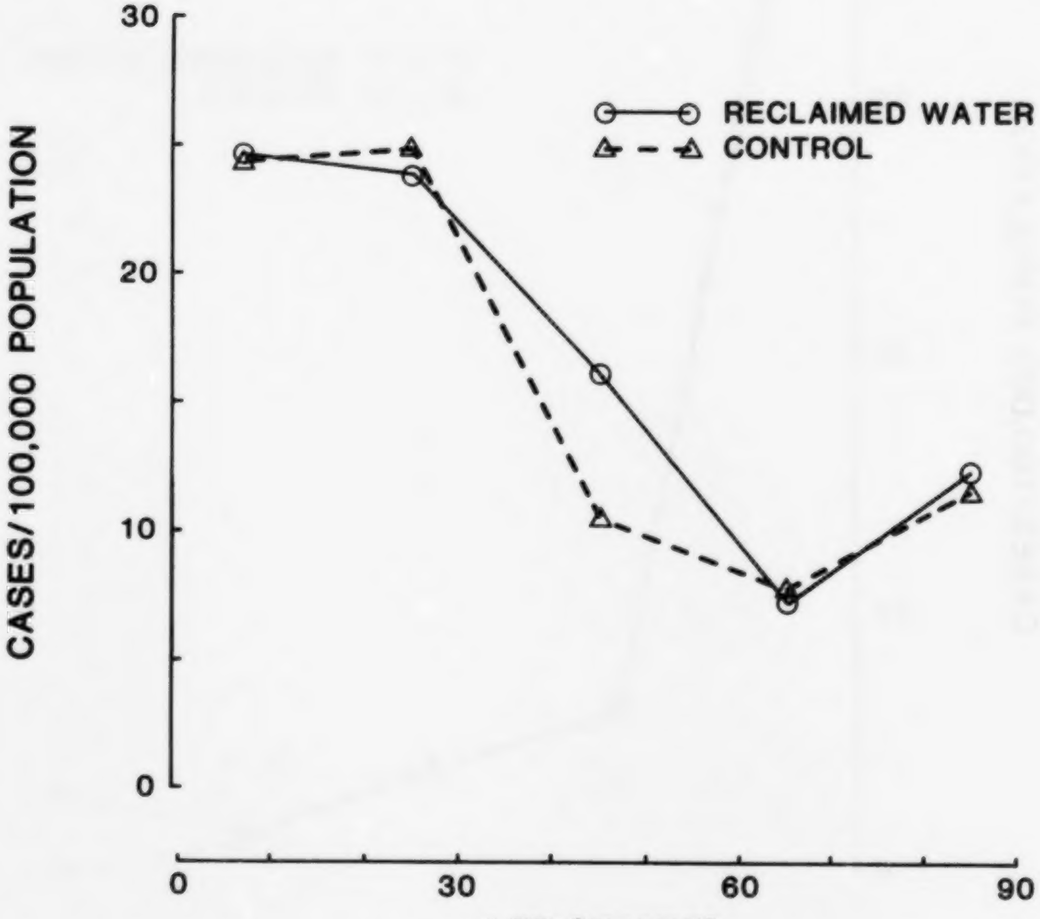


FIGURE O-32
INCIDENCE RATES BY AGE AND STUDY AREA
SHIGELLOSIS 1979-80

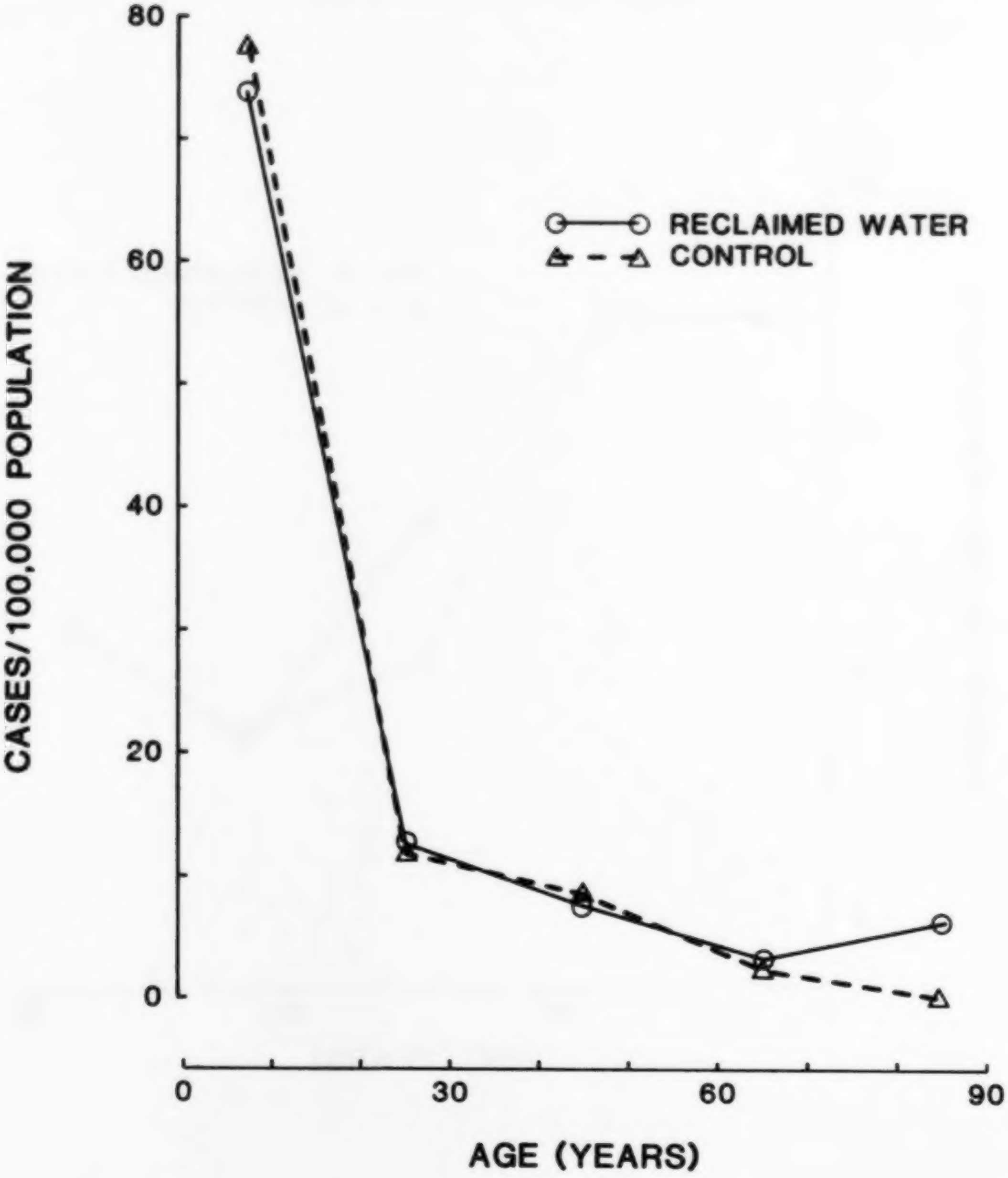


FIGURE O-33
PROPORTION WEIGHING ≤ 1,500 OR ≤ 2,500 GRAMS AT BIRTH BY AGE OF MOTHER AND STUDY AREA 1979-80

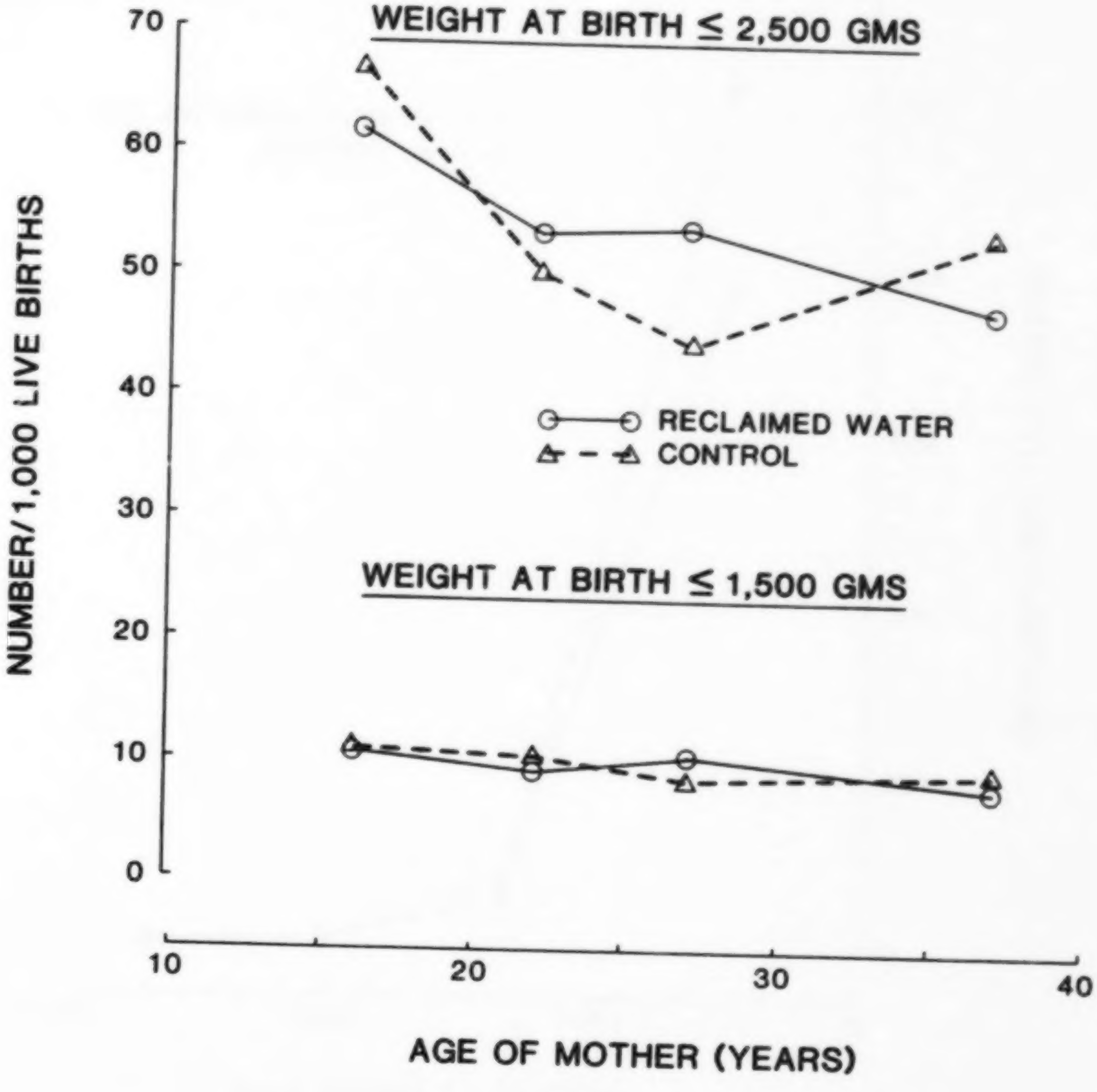


FIGURE O-34

MORTALITY RATES BY BIRTH WEIGHT AND STUDY AREA FIRST YEAR OF LIFE 1979-80

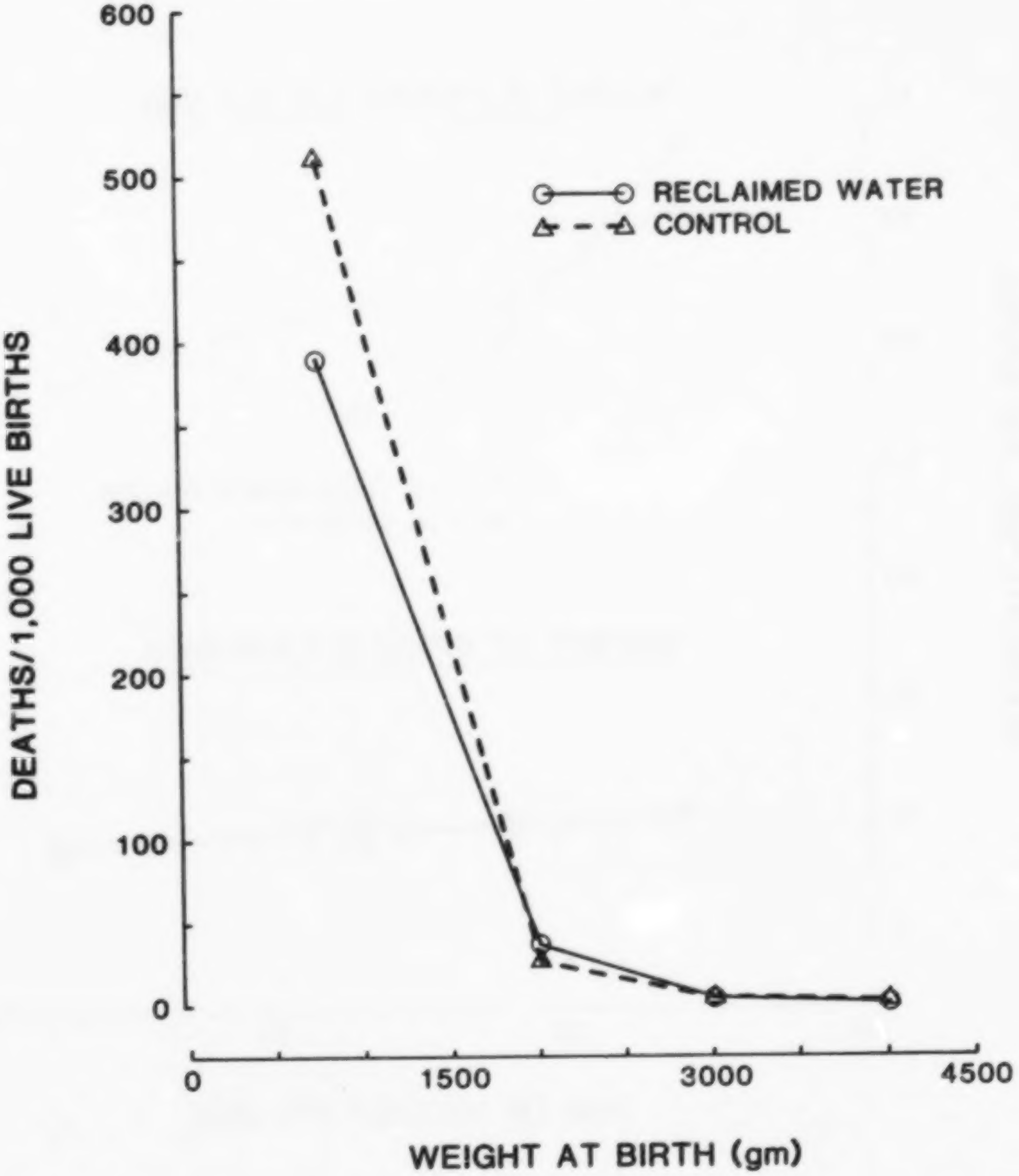
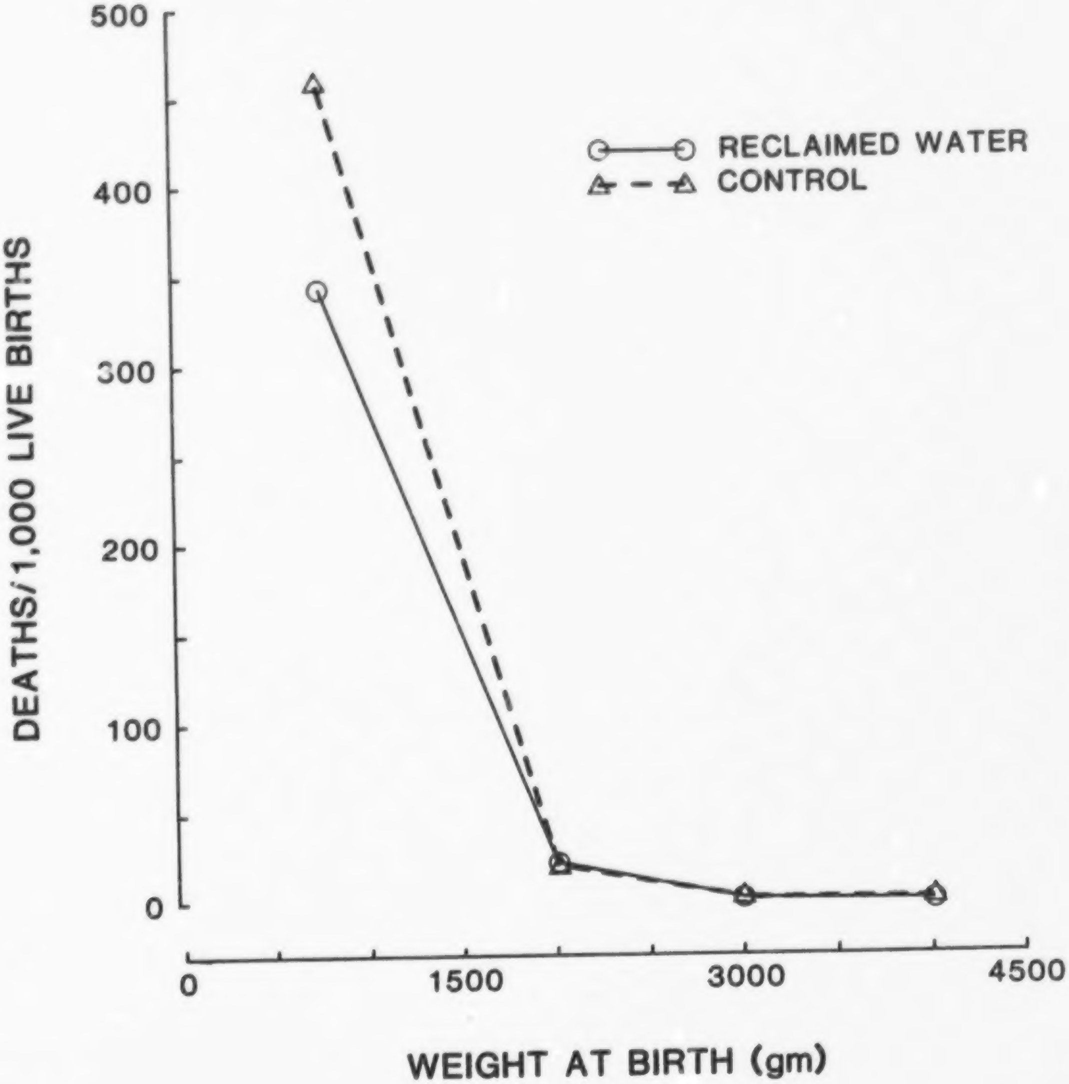


FIGURE O-35

MORTALITY RATES BY BIRTH WEIGHT AND STUDY AREA FIRST 27 DAYS OF LIFE 1979-80



UNIVERSITY OF CALIFORNIA, LOS ANGELES

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INSTITUTE FOR SOCIAL SCIENCE RESEARCH
SURVEY RESEARCH CENTER
LOS ANGELES, CALIFORNIA 90024

Dear Los Angeles Resident:

We need your help in conducting a health survey. As you may know, over seven million people live in Los Angeles County. We work at different jobs, live in different communities, and have different interests. We also have had different experiences with health and illness, and different ideas about the environment in which we live. Because we think your opinions are important matters in decisions about the environment, the Survey Research Center at UCLA is conducting a survey to give residents of several communities in Los Angeles County the opportunity to contribute to the current knowledge of these issues.

Your household is part of a randomly selected sample of residents of several communities in Los Angeles County. By interviewing women in selected households such as your own, we can be sure we have represented the experience of other Los Angeles women like yourself. The more women who cooperate, the more successful we can be in reporting on women's health and ideas about the environment. We feel you will find that our questions will give you an opportunity to express your opinions on some topics and issues of great importance to us all at this time.

In the next few weeks, one of our interviewers will call at your home. Your interviewer will carry a blue identification card that looks like the example reproduced at the bottom of this letter. Please ask that this identification card be shown so you will know that the person at your door is a registered Survey Research Center interviewer. You will be asked for some information about your household, and we ask your cooperation in answering these questions so the interviewer can select the member of your household who is to be interviewed. Since we will not know until that time who the selected person is, I would appreciate your showing this letter to any members of your household who are age 18 or over. That way they will also know about the survey and can ask for identification when our interviewer calls at your home.

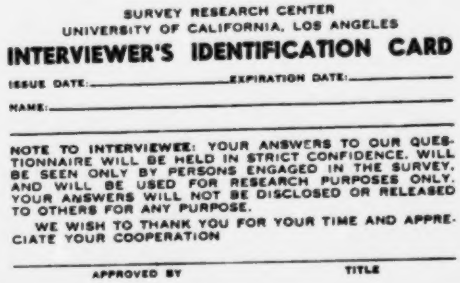
I wish to assure you that the opinions and information you provide will be held in the strictest confidence within the limits provided by law, and will be published only in the form of statistical summaries. No individuals or families will be identified. However, to present an accurate picture of your community and its people, your participation in this survey is most important.

Let me thank you in advance for your cooperation.

Sincerely,

Vi Dorfman

Vi Dorfman
Field Supervisor



SURVEY RESEARCH CENTER
UNIVERSITY OF CALIFORNIA, LOS ANGELES

INTERVIEWER'S IDENTIFICATION CARD

ISSUE DATE: ________ EXPIRATION DATE: ________

NAME: ________

NOTE TO INTERVIEWEE: YOUR ANSWERS TO OUR QUESTIONNAIRE WILL BE HELD IN STRICT CONFIDENCE. WILL BE SEEN ONLY BY PERSONS ENGAGED IN THE SURVEY, AND WILL BE USED FOR RESEARCH PURPOSES ONLY. YOUR ANSWERS WILL NOT BE DISCLOSED OR RELEASED TO OTHERS FOR ANY PURPOSE.

WE WISH TO THANK YOU FOR YOUR TIME AND APPRECIATE YOUR COOPERATION

APPROVED BY ________ TITLE ________

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INSTITUTE FOR SOCIAL SCIENCE RESEARCH
SURVEY RESEARCH CENTER
LOS ANGELES, CALIFORNIA 90024

January 1981

Dear Los Angeles Resident:

This letter will introduce ___________________, a field interviewer for the Institute for Social Science Research, Survey Research Center of UCLA. We are conducting a study among women in several communities in Los Angeles County regarding their health, illness, and the environment. Your cooperation on this important study is urgently needed. It is only through your help that the study can be a success. Please be assured that all answers you give our interviewer will be confidential within the limits provided by law.

Sincerely yours,

Vi Dorfman

Vi Dorfman
Supervisor of Field Operations

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SURVEY RESEARCH CENTER
LOS ANGELES, CALIFORNIA 90024

R I.D.#________________

Environmental Health Survey

Informed Consent Statement

The Environmental Health Survey is a study of women's health and their attitudes toward the environment. You have been chosen as part of a random sample of women living in several communities in Los Angeles County. It is the goal of this study to provide information which is necessary for developing policies concerning the environment.

Participation in the Environment Health Survey consists of a single personal interview in your home that will take from 10 to 20 minutes.

We are asking that you allow us to include you in this study. Please understand that your participation is voluntary. You may refuse to answer any question or withdraw your consent and discontinue participation in this study at any time. To indicate your informed consent we would like you to sign this statement, a copy of which will be left with you.

All information obtained from you will have full protection of confidentiality within the limits provided by law and will be used only for statistical purposes. Your name will not be associated in any way with the information you give us, or with the results of this study.

I understand that Dr. Ralph Frerichs, DrPH, who can be reached at 825-3286, will answer any questions concerning the details of this study. If the study design or use of the data is to be changed, I will be so informed and my consent reobtained. I also understand that if I have any questions, comments or concerns about the study or the informed consent process, I may address them to Vice-Chancellor A. A. Barber at 3134 Murphy Hall, UCLA, Los Angeles, California 90024, or (213)825-8714.

I understand the above and agree to participate in this study.

SIGNATURE:________________________________

DATE:________________________________

INTERVIEWER'S SIGNATURE:________________________________

ENVIRONMENTAL HEALTH SURVEY #2049 DECK 01
(6-7)

I.D.#__________
(1-5)

(SCREENER)

	DATE	INIT
LOG 1		
LOG 2		
EDIT		
VAL		
CLN		

INFORMATION TO FIELD OFFICE: __________ / __________ MONTH DAY

TELEPHONE #: __________ / __________ (8-10) AREA CODE (11-13)

INTERVIEWER NAME: ____________________ (17) (18-21)

I.D.#: __________ (14-16)

DATE	DAY	TIME	TYPE	RESULT	COMMENTS
1.		AM PM	P/T		
2.		AM PM	P/T		
3.		AM PM	P/T		
4.		AM PM	P/T		
5.		AM PM	P/T		
6.		AM PM	P/T		
7.		AM PM	P/T		
8.		AM PM	P/T		
9.		AM PM	P/T		
10.		AM PM	P/T		
11.		AM PM	P/T		
12.		AM PM	P/T		
13.		AM PM	P/T		
14.		AM PM	P/T		
15.		AM PM	P/T		

NO ANSWER	01	# DISCONNECTED/NOT IN SERVICE	08
R NOT AVAILABLE	02	NONRESIDENTIAL #	09
LINE BUSY	03	COMPLETED	10
WRONG NUMBER	04	INITIAL CONTACT REFUSED	11
ANSWERING SERVICE/RECORDED MESSAGE	05	R REFUSED	12
LANGUAGE BARRIER	06	TERMINATED	13
CALL BACK ARRANGED	07	INCAPABLE	14
		OTHER	15

FOR OFFICE USE ONLY:

FINAL RESULT - ☐☐

I.D.#: ____________________ Telephone #: ____________________

Screener

Good morning/afternoon/evening. I'm (...) from the Institute for Social Science Research at UCLA. We are conducting a survey sponsored by the Environmental Protection Agency to learn about the health of women living in several communities in L.A. County.

1. Is this (REPEAT # DIALED)?

YES.................CONTINUE............ 1
NO..................TERMINATE,
DIAL AGAIN.......... 2

As part of our study, we are interviewing a random sample of women in several communities in L.A. County about health, illness and the environment. All responses to the interview are confidential within the limits provided by law; your name will not be connected in any way with the findings of the study. Although you have the right to refuse to participate or to withdraw at anytime, we would greatly appreciate your participation in the study. If you have any questions about the study, you may communicate them to Vice-Chancellor A. A. Barber at 3134 Murphy Hall, UCLA, Los Angeles, California 90024 or at (213) 825-8714, or call Vi Dorfman at the Institute for Social Science Research at 825-8437.

2. Have I reached you on your home phone?

YES.................SKIP TO Q4.......... 1
NO..................ASK Q3.............. 2

3. Does anyone live there?

YES.................ASK Q4.............. 1
NO..................TERMINATE........... 2

4. May I speak to an adult 18 years or older who lives there?

IF AN ADULT IS SPEAKING, CONTINUE WITH Q5.

IF SOMEONE UNDER 18 ANSWERED THE PHONE, BUT AN ADULT IS AVAILABLE, ASK TO SPEAK TO THE ADULT, REINTRODUCE YOURSELF, STATE PURPOSE, AND START AT Q1 AGAIN.

IF AN ADULT IS NOT AVAILABLE, ARRANGE CALLBACK.

DAY: ________________ TIME: ______________

DECK 01

5. Is your address:

____

____

____

ADDRESS CORRECT.....ASK Q6.............. 1
NOT CORRECT.........TERMINATE........... 2

6. How many females 18 years old or older live at this address? How many males 18 or over?

FEMALES:________________ (33-34)

MALES:________________ (35-36)

IF "0" FEMALES...............TERMINATE........... 1 (37)
IF 1 OR MORE FEMALES.........CONTINUE............ 2

7. Please tell me the first names of the females 18 years or over who are members of your household. This will tell me who I am to interview.

A.	B. Is (...) a permanent resident?		C. Sex		D. Age on Last Birth day	E. Number and circle # Selected	F. Relationship to Respondent	G. Current Marital Status				
First Name	YES	NO	M	F				Nev Mar	Married	Div	Sep	Wid
			38	2	44-45	56	62-63	1	2	3	4	5 74
			39	2	46-47	57	64-65	1	2	3	4	5 75
			40	2	48-49	58	66-67	1	2	3	4	5 76
			41	2	50-51	59	68-69	1	2	3	4	5 77
			42	2	52-53	60	70-71	1	2	3	4	5 78
			43	2	54-55	61	72-73	1	2	3	4	5 79

IF NOT A PERMANENT RESIDENT, REMOVE (...) FROM ROSTER. RELIST MEMBERS IN ORDER (DO NOT SKIP A LINE NUMBER).

IF NO WOMAN IS A PERMANENT RESIDENT AT THIS ADDRESS, HOUSEHOLD BECOMES UNQUALIFIED.

OFFICE USE ONLY: LINE NUMBER OF RESPONDENT__________ (80)

8. Please give me the first names of the males 18 years old or over who are members of your household.

BEGIN DECK 02

A.	B. Is (...) a permanent resident?		C. Sex		D. Age on Last Birth day	F. Relationship to Respondent	G. Current Marital Status				
First Name	YES	NO	M	F			Nev Mar	Married	Div	Sep	Wid
			1	8	14-15	26-27	1	2	3	4	5 38
			1	9	16-17	28-29	1	2	3	4	5 39
			1	10	18-19	30-31	1	2	3	4	5 40
			1	11	20-21	32-33	1	2	3	4	5 41
			1	12	22-23	34-35	1	2	3	4	5 42
			1	13	24-25	36-37	1	2	3	4	5 43

9. And finally, please give me the first names of those members of your household who are less than 18 years old.

A. BEGIN DECK 03 First Name	B. Sex M	 F	C. Age on Last Birthday	D. Relationship to Respondent
	8 1	2	19-20	41-42
	9 1	2	21-22	43-44
	10 1	2	23-24	45-46
	11 1	2	25-26	47-48
	12 1	2	27-28	49-50
	13 1	2	29-30	51-52
	14 1	2	31-32	53-54
	15 1	2	33-34	55-56
	16 1	2	35-36	57-58
	17 1	2	37-38	59-60
	18 1	2	39-40	61-62

IF 1 ELIGIBLE FEMALE IN HH.......DETERMINE IF R IS AVAILABLE........ 1

IF 2 OR MORE ELIGIBLE FEMALES
IN HH............................MAKE SELECTION FOR R, AND
DETERMINE IF R IS AVAILABLE........ 2

IF R IS AVAILABLE, CONTINUE WITH INTERVIEW.

IF R IS NOT AVAILABLE, ARRANGE FOR A CALL BACK.

DAY:________________ TIME:_____________

#2049

ENVIRONMENTAL HEALTH SURVEY

R.I.D.:_______________ #2049 - 1 - 81 64-66/

67-70/

A1. INTERVIEWER:______________________________ I.D.#:_______________ 71-74/

A2. TIME BEGINNING:________ AM PM TIME ENDING:________ AM PM # OF MINUTES:______ 75-77/

BEGIN DECK 04

1. I'd like to begin by asking, how many years out of the past 10 years have you lived in Los Angeles County?

RECORD # YEARS:_________________ (8-9)

IF LESS THAN 1 YEAR,
RECORD # MONTHS:_________________ (10-11)

2. How long have you lived at your present address?

UNDER 1 YEAR	01	(12-13)
1 - 2 YEARS	02	
3 - 4 YEARS	03	
5 - 6 YEARS	04	
7 - 8 YEARS	05	
9 - 10 YEARS	06	
11 OR MORE YEARS	07	
ALL MY LIFE	08	

3. Do you own or rent your home?

OWN	1	(14)
RENT	2	
OTHER	3	

→SPECIFY:_________________________

Now, a few questions about your health in general.

4. **How would you rate your health overall? Compared to other women of your age, would you say your health is:**

Excellent,	1	(15)
Good,	2	
Fair, or	3	
Poor?	4	
NO ANSWER	9	

DECK 04

In the next few questions, I am going to ask you about events that have occurred during the past two months, that is, since (16-17)

(18-19)

________________ ________________.
MONTH DAY

5. Thinking back over the past two months, did you stay in bed all or part of any day because of any illness or injury?

YES.................ASK A............... 1 (20)
NO..................SKIP TO Q6.......... 2

A. How many days did you stay in bed for all or part of the day during the past two months, because of illness or injury? (COUNT "PART" DAYS AS WHOLE.)

RECORD # DAYS:________________ (21-22)

6. (Besides the days in bed) Were there (any/any other) days during the past two months that you had to cut down on the things you usually do, because of poor health?

YES.................ASK A............... 1 (23)
NO..................SKIP TO Q7.......... 2

A. (Not counting the days in bed) How many (other) days during the past two months did you have to cut down, for as much as a day, on things you usually do, because of poor health?

RECORD # DAYS:________________ (24-25)

7. Are you currently limited in your work or other activities in any way because of your health or because of a disability?

YES..................................... 1 (26)
NO...................................... 2

DECK 04

8. During the past two months, have you had any medical problems that were serious enough to require contacting a medical doctor or other health professional?

YES..................ASK A................ 1 (27)
NO...................SKIP TO Q9.......... 2

A. How many times during the past two months did you see or talk to a medical doctor or other health professional about these problems?

RECORD # TIMES:______________ (28-29)

B. What did the doctor or other health professional say is your problem? RECORD BELOW.

FIRST PROBLEM:______________________________ (30-32)
SECOND PROBLEM:_____________________________ (33-35)
THIRD PROBLEM:______________________________ (36-38)
FOURTH PROBLEM:_____________________________ (39-41)

9. During the past two months, have you been admitted to a hospital and stayed at least a full day or night?

YES..................ASK A................ 1 (42)
NO...................SKIP TO BOX BEFORE Q10.......... 2

A. How many separate times during the past two months were you admitted to a hospital to stay at least a full day or night?

RECORD # TIMES:______________ (43-44)

RECORD UP TO THREE MENTIONS IN CHART BELOW

B. What was the matter? PROBE Does it have a medical name? RECORD.	C. How many full days or nights did you stay in the hospital for (...) problem during the past two months? RECORD # OF DAYS
FIRST TIME:______________ (45-48)	______________ (49-50)
SECOND TIME:______________ (51-54)	______________ (55-56)
THIRD TIME:______________ (57-60)	______________ (61-62)

AGE OF RESPONDENT: ____________ (63-64)

IF 46 YEARS OR OLDER..........SKIP TO COMMENTS BEFORE Q19... 1 (65)
IF 45 YEARS OR YOUNGER........CONTINUE...................... 2

BEGIN
DECK 05

Now, I'd like to ask you some questions about any pregnancies you may have had during the last five years, that is, since

____________ of ____________.
MONTH YEAR

10. Have you been pregnant in the last five years?

YES.................ASK Q11............. 1 (8)
NO..................SKIP TO Q14......... 2
DNA.................SKIP TO Q14......... 3

11. How many times have you been pregnant in the last five years? Please include miscarriages, abortions, and stillbirths.

RECORD # TIMES: ____________ (9-10)

12. (Thinking about your pregnancies in the last five years,) Did your (...) pregnancy end in:

ASK ABOUT EACH PREGNANCY INSERTING 1ST, 2ND, ETC. FOR (...). CODE ANSWER IN THE APPROPRIATE COLUMN OF THE CHART.

A miscarriage or
abortion,................ASK A
A stillbirth,............CODE AND SKIP TO NEXT PREGNANCY OR Q13
Or a live birth?.........CODE AND SKIP TO NEXT PREGNANCY OR Q13

A. Was the miscarriage or abortion spontaneous or was it induced?

SPONTANEOUS.............CODE AND SKIP TO NEXT PREGNANCY OR Q13
INDUCED.................CODE AND SKIP TO NEXT PREGNANCY OR Q13

FOR MISCARRIAGES/ABORTIONS, CODE ANSWER IN COLUMN I OR II OF THE CHART.

IF R REPORTS TWINS, RECORD THE APPROPRIATE CODE (2-5) FOR EACH OF THE TWINS IN COLUMN V.

DECK 05

	I	II	III	IV	V
Pregnancy	Miscarriage or Spontaneous Abortion	Induced Abortion	Still-birth	Live Birth	Twins
1st	2	3	4	5 (11)	Twin 1______ Twin 2______ (12)
2nd	2	3	4	5 (13)	Twin 1______ Twin 2______ (14)
3rd	2	3	4	5 (15)	Twin 1______ Twin 2______ (16)
4th	2	3	4	5 (17)	Twin 1______ Twin 2______ (18)
5th	2	3	4	5 (19)	Twin 1______ Twin 2______ (20)
6th	2	3	4	5 (21)	Twin 1______ Twin 2______ (22)
7th	2	3	4	5 (23)	Twin 1______ Twin 2______ (24)

IF "0" LIVE BIRTHS (NO CODE '5')..SKIP TO Q14......... 1
IF ONE OR MORE LIVE BIRTHS.......CONTINUE............ 2

DECK 05

13. During these last five years, were any of your children born with any birth defects?

YES.................ASK A............... 1 (25)
NO..................SKIP TO Q14......... 2

A. How many of your children born during the last five years had a defect?

RECORD NUMBER:________________ (26-27)

B. What was the nature of the defect(s)? RECORD VERBATIM.

____ (28-29)
____ (30-31)

14. Was there a time during the last five years when you were trying to become pregnant and either could not do so or it took more than six months to do so?

YES.................ASK A............... 1 (32)
NO..................SKIP TO Q15......... 2

A. In the last five years, what is the longest period of time during which you tried to become pregnant and were unsuccessful?

RECORD # OF MONTHS:________________ (33-34)
(6-11)
IF MORE THAN 11 MONTHS,
RECORD # OF YEARS:________________ (35-36)

15. During the last five years, have you seen a doctor about problems with your menstrual periods?

YES.................ASK A............... 1 (37)
NO..................SKIP TO Q16......... 2
DNA.................SKIP TO Q16......... 3

A. What was the problem? RECORD VERBATIM.

____ (38-39)
____ (40-41)
____

16. How many times in your entire life have you been pregnant? Please include the pregnancies you may have already mentioned for the last five years and all other pregnancies. Remember to include all miscarriages, abortions, stillbirths, and live births.

RECORD TOTAL #
OF PREGNANCIES:_______________ (42-43)

NONE........SKIP TO INTRO ABOVE Q19.....90

17. How many of these pregnancies lasted 7 months (28 weeks) or longer?

RECORD TOTAL # OF
PREGNANCIES LASTING
28 WEEKS OR MORE:_____________ (44-45)

18. How many live births have you had altogether?

RECORD TOTAL #
OF LIVE BIRTHS:_______________ (46-47)

Now, I would like to switch topics and ask a few questions about your drinking water.

19. Do you currently buy bottled water for drinking and cooking at home? By bottled water, I mean water delivered to your home, like Sparkletts or Arrowhead, or water you buy at the market. We are not interested in water you buy for anything other than drinking or cooking.

YES.................ASK A............... 1 (48)
NO..................SKIP TO Q20......... 2

A. How long have you been using bottled water in your home?

RECORD # OF YEARS:____________ (49-50)

IF LESS THAN 1 YEAR,
RECORD # OF MONTHS:___________ (51-52)

B. How many bottles of bottled water do you use in your home each month? Please include water you buy at the store or have delivered to your home.

RECORD # OF BOTTLES:__________ (53-54)

C. What size bottles do you use?

1-GALLON BOTTLES........................01
5-GALLON BOTTLES........................02 (55-56)
OTHER...................................03
→SPECIFY:_____________________________

DECK 05

D. Do you use bottled water for:

Drinking,...........ASK E............... 1 (57)
Cooking, or.........SKIP TO F........... 2
Both?...............ASK E............... 3

E. Thinking about the bottled water you drink at home, about how many cups or glasses of bottled water do you drink in a typical weekday? Please include coffee, tea, and juices made with bottled water. Please do not include any bottled water you drink away from home; we are only interested in what you drink at home.

RECORD CUPS/GLASSES
PER TYPICAL DAY:______________ (58-59)

F. Why did you decide to use bottled water? CODE ALL MENTIONS.

CONCERN FOR HEALTH...................... 1 (60)
DID NOT LIKE TASTE, ODOR OR
APPEARANCE OF TAP WATER................. 2 (61)
OTHER................................... 3 (62)
→SPECIFY:______________________________

20. Do you use tap water for:

Drinking,...........ASK A............... 1 (63)
Cooking, or.........SKIP TO Q21......... 2
Both?...............ASK A............... 3
NEITHER.............SKIP TO Q21......... 4

A. Thinking about the tap water you drink at home, about how many cups or glasses of tap water do you drink in a typical weekday? Please include coffee, tea, and juices made with tap water. Please do not include the tap water you drink away from home; we are only interested in what you drink at home.

RECORD CUPS/GLASSES
PER TYPICAL DAY:______________ (64-65)

B. Do you use any kind of water filter on your kitchen faucet at home?

YES..................................... 1 (66)
NO...................................... 2

21. Now, I would like to ask you some questions about alcoholic beverages. Thinking about the past year, have you had at least five drinks of beer, wine or liquor?

YES..................ASK Q22.............. 1 (67)
NO...................SKIP TO Q24......... 2

22. How often do you usually drink beer, wine, or liquor? Would you say:

Rarely (ABOUT ONCE A MONTH),............ 1 (68)
Occasionally (A FEW TIMES A MONTH),..... 2
Frequently (A FEW TIMES A WEEK), or..... 3
Often (EVERYDAY OR ALMOST EVERYDAY)?.... 4
NO ANSWER.............................. 9

23. When you drink beer, wine, or liquor, about how much do you drink in one sitting?

1 GLASS/BOTTLE/CAN/SHOT................. 1 (69)
2-4 GLASSES/BOTTLES/CANS/SHOTS.......... 2
5 OR MORE GLASSES/BOTTLES/CANS/SHOTS.... 3
NO ANSWER.............................. 9

24. Do you smoke cigarettes?

YES..................ASK A............... 1 (70)
NO...................SKIP TO COMMENT
BEFORE Q25.......... 2

A. On the average, about how many cigarettes do you smoke per day?

LESS THAN ½ PACK (10 OR LESS)........... 1 (71)
½ PACK (11-19).......................... 2
1 PACK (20-29).......................... 3
1½ PACKS (30-39)........................ 4
2 PACKS (40-59)......................... 5
3 OR MORE PACKS PER DAY (60+)........... 6

BEGIN
DECK 06

I would now like to get some impression of how you feel about your community.

25. How do you feel about the neighborhood you live in? Would you say you are:

Very satisfied,	1	(8)
Pretty satisfied,	2	
Not too satisfied, or	3	
Not satisfied at all with your neighborhood?	4	
NO ANSWER	9	

26. How would you rate the air quality where you live? Would you say the air quality is:

Very good,	1	(9)
Pretty good,	2	
Not too good, or	3	
Poor?	4	
NO ANSWER	9	

27. How would you rate the quality of the drinking water in your area? Would you say the water is:

Very good,	1	(10)
Pretty good,	2	
Not too good, or	3	
Poor?	4	
NO ANSWER	9	

That ends the health and environmental section of the interview. And now, a few final background questions.

28. What is the highest grade in school you completed and received credit for? (CIRCLE ONE.)

00 01 02 03 04 05 06 07 08 09 10 11 12

COLLEGE/OTHER POST HIGH SCHOOL SCHOOLING 13 14 15 16 (11-12)

POST GRADUATE SCHOOL 17 18 19 20 OR MORE

29. Now, I'm going to ask about your employment. As I read you the following employment categories, please tell me which category best describes your current employment status. Are you:

Working full-time,..ASK A.............. 1 (13)
Working part-time,..ASK A............... 2
Keeping house,......SKIP TO Q30......... 3
Retired,............SKIP TO Q30......... 4
A student,..........SKIP TO Q30......... 5
Unemployed, or......SKIP TO Q30......... 6
Something else?.....SKIP TO Q30......... 7
→SPECIFY:______________________________

A. What kind of work do you do? What is your main occupation? (EXAMPLES: LAWYER, SALESCLERK, SECRETARY, TEACHER(SCHOOL LEVEL))

____ (14-16)

____

B. What kind of business, industry, or organization do you work for? What do they do or make? (EXAMPLES: DEPARTMENT STORE, BUSINESS FIRM, CITY SCHOOL DISTRICT)

____ (17-19)

____

Duncan (20-21)R

30. To help us classify our answers, we would like to know your racial background. Which one of the following do you most closely identify with:

White/Caucasian,........................ 1 (22)
Black/Negro/Afro-American,.............. 2
Asian/Asian-American/Oriental, or....... 3
Native American/American Indian?........ 4
OTHER................................... 5
→SPECIFY:______________________________
REFUSED................................. 9

DECK 06

31. Do you consider yourself to be of Chicano or Mexican descent?

YES..................SKIP TO Q33......... 1 (23)
NO..................ASK Q32............. 2
REFUSED.............ASK Q32............. 9

32. Do you consider yourself to be of other Spanish descent?

YES..................................... 1 (24)
NO...................................... 2
REFUSED................................. 9

33. Was any language other than English spoken in your home when you were a child?

YES..................ASK A............... 1 (25)
NO..................SKIP TO Q34......... 2

A. Could you tell me what other language was spoken in your home when you were a child?

SPANISH..................................01 (26-27)
FRENCH...................................02
GERMAN...................................03
JAPANESE.................................04
CHINESE..................................05
OTHER....................................96
- SPECIFY: ______________________

DECK 06

34. Is any language other than English spoken in your present household?

YES.................ASK A............... 1 (28)
NO..................SKIP TO Q35......... 2

A. Could you tell me what other language is spoken in your present household?

SPANISH.................................01 (29-30)
FRENCH..................................02
GERMAN..................................03
JAPANESE................................04
CHINESE.................................05
OTHER...................................96
SPECIFY: ______________________________

35. Finally, may I have your full name (and address/telephone number)? Again, I want to assure you that this information will be held confidential to the limits provided by law. (This means it cannot be released without an order from a court.)

NAME: ____
FIRST LAST

ADDRESS: ____
AND STREET

____
CITY ZIP CODE

TELEPHONE NUMBER: ____________/______________________
AREA CODE

NO PHONE................................90

Thank you for your time.

That concludes our interview. Do you have any questions or comments?

____

____

____

TIME ENDED: __________

DECK 06

INTERVIEWER INFORMATION

NAME:______________________________

INTERVIEWER I.D.:________________________

LABEL I.D.:__________________________

DATE:_________/_________/_________
MONTH (31-32) DAY (33-34) YEAR

INTERVIEW CONDUCTED IN ENGLISH...............	1	(35)
INTERVIEW CONDUCTED IN SPANISH...............	2	
INTERVIEW CONDUCTED IN PERSON................	1	(36)
INTERVIEW CONDUCTED ON TSM...................	2	
INTERVIEW CONDUCTED BY TELEPHONE.............	3	